NATIONAL PHYSICAL LABORATORY.

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MINUTES OF EVIDENCE

TAKEN BEFORE THE

COMMITTEE

APPOINTED BY THE TREASURY

TO CONSIDER THE DESIRABILITY OF ESTABLISHING

A

NATIONAL PHYSICAL LABORATORY:

WITH

APPENDICES AND INDEX.

Presented to both Houses of Parliament by Command of Her Majesty

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MINUTES OF EVIDENCE

TAKEN BEFORE THE

COMMITTEE APPOINTED TO CONSIDER

THE DESIRABILITY OF ESTABLISHING A

NATIONAL PHYSICAL LABORATORY

AT 32 ABINGDON STREET, WESTMINSTER, S.W.

Monday, October 18th, 1897.

PRESENT:

The LORD RAYLEIGH, D.C.L., F.R.S. (*Chairman.*)

Sir COURTENAY BOYLE, K.C.B.
Sir JOHN WOLFE BARRY, K.C.B., F.R.S.
Mr. W. C. ROBERTS-AUSTEN, C.B., F.R.S.
Mr. ROBERT CHALMERS.
Mr. A. W. RÜCKER, D.Sc., F.R.S.
Mr. ALEXANDER SIEMENS.
Dr. T. E. THORPE, F.R.S.

Mr. L. BLAIKIE, *Secretary.*

SIR DOUGLAS GALTON, K.C.B., F.R.S., called; and Examined.

Sir Douglas Galton, K.C.B., F.R.S.
18 October 1897.

1. (*Chairman.*) We know that the matter which has been referred to this Committee is one which has occupied your attention a good deal, and that in fact it was largely owing to your action as President of the British Association that the question has arrived at its present stage; therefore, acting for the Committee, I thought that it would be proper that we should learn from you the information that you have collected upon this subject, and any views at which you have arrived?—My attention was first drawn to the question through being Secretary of the British Association for so many years. The Kew Observatory has been founded by the British Association, and was supported by it out of considerable subscriptions from its funds, until the time when Mr. Gassiot endowed it, and placed it in the hands of trustees under the Royal Society, under whom it is now. Its objects were practically explained to be in its earlier inception somewhat on the lines of those of the Reichsanstalt at Berlin, because the work which was proposed to be done under the British Association was partly research in connection with electricity, magnetism, meteorological conditions at different elevations and temperatures, pendulum experiments for the Indian Survey, and various matters of that sort. Then it also had investigations into the best forms of barometers; it undertook the verification of barometers and thermometers, and the testing of chronometers for the public. Lord Kelvin, when he was President of the British Association in 1871, I think, expressed very strongly the importance of having a national physical laboratory or something of the sort, and Professor Oliver Lodge at Cardiff, in 1890, I think——

2. In 1891, I think it was?—At Cardiff at any rate he urged the matter very strongly, and explained rather fully what he wished done, so that my attention was first drawn to it in that way. Then when I became President I thought that as I was taking a review of the work of the British Association it would be desirable for me just to allude to what was being done on the Continent in those matters, and then I went over to Berlin and examined the Reichsanstalt. The French Observatory upon similar lines which is supported by the Government I thought was sufficiently well known, and I did not go over there, but the Reichsanstalt was a new establishment, and therefore I thought it desirable to go and make some reference to it. That is the way that I came to draw attention to it first of all in my Presidential Address, and next in a short paper which I read before the Association at Ipswich. That paper was referred to a Committee of the Association, that Committee reported in 1896 at Liverpool; and that Report of the Committee in 1896 was followed by a memorial, signed by a large number of scientific men. I could hand those papers in so that they might go on record if the Committee think it desirable. I have just brought those facts together, because I thought it would be desirable that you should have before you the inception of this subject in England.

3. You were personally acquainted with the Berlin Institution at the time of your Presidential Address, I believe?—Yes, I went there purposely in the spring before delivering the Presidential Address in order to examine it.

4. It was in consequence of your Address and of a paper you afterwards read to Section A, I think, that a Committee was formed to further consider the matter?—Yes, I have here reports which give very full particulars of the Reichsanstalt. When I visited Berlin in 1895 the Reichsanstalt was only partially completed, there being only one division finished. The Reichsanstalt consists of two divisions. I can, if wished, hand in a copy of the rules which have been translated by Mr. Siemens, a member of this Committee. The functions of the first department of the Reichsanstalt are defined to be the carrying out of physical investigations and measurements which aim at the solution of scientific problems, either of a theoretical or technical character, which are of greater scope and importance, and which require a greater expenditure in the preparation of instruments or use of materials, and time of observers and calculators, than as a rule can be expected from either private individuals or educational establishments. The second function of the first department is the solution of problems arising in the work of the second division of the Reichsanstalt, which the means at the disposal of the second division do not suffice to meet. The functions of the second department are summarised as follows:— The carrying on of physical researches of a technical character which are either ordered by superior authority or which are of a character to forward mechanical work of precision—I do not quite know how to translate the words used there—Präzisions mechanik—and I do not know whether I am right in taking them to mean "mechanical work of precision"—and to advance as far as possible other objects of the Germans in their technical work. They classify the whole of the second department under the following sub-

Sir Douglas Galton, K.C.B., F.R.S.

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heads—investigations into the nature of materials; investigations into sound methods for preparing materials; investigations into methods of construction which are best suited to effect their object; and into methods for preparing physical and technical measuring apparatus—perhaps Mr. Siemens has put this better than I have done it, I will not be certain. The next sub-head is the verification of measuring apparatus and of instruments of control so far as they do not fall within the province of the laws regulating measures and weights, and the determination of the errors in instruments and scales submitted for testing and certifying the results.

5. (*Sir Courtenay Boyle.*) Can you develop a little that sub-head relating to measures and scales; are they commercial measures and scales, or what measures and scales are they?—They are chiefly scientific measures and scales for scientific investigations, I apprehend.

6. I mean a quart pot is a measure?—That does not come under this head; it falls under the department of weights and measures; but perhaps Mr. Siemens's translation might be a better one than mine.

7. *(Mr. Siemens.)* It is for the granting of certificates for measuring apparatus and standard instruments not included under the laws of weights and measures, the determination of errors in the divisions of such instruments, and certifying the results obtained—that is for voltmeters, ammeters, and that sort of thing?—The next sub-head is the preparation of instruments or parts of instruments which are required for advancing mechanical work which is either being done by the Reichsanstalt, or which is required for other scientific institutions or authorities under the German Government, and also for assisting private German enterprise in difficulties which it may encounter. The next sub-head is the preparation of materials for private German establishments in special cases where private workshops demand extraordinary means of help. The expenditure incurred under the two last heads is reimbursed by the private persons who require the assistance at the rate of the full cost of the materials and double the charge incurred for labour. The actual work which has been carried on has been published in a series of annual reports, and I have brought almost all of them with me, in order to hand them in to you if you should desire them. I have made a sort of summary of what they are doing now at the present time, which I think will explain what they really do better than merely telling you what their functions are.

8. (*Chairman.*) It will explain it, you mean, by actual example?—Yes; I may mention that very full particulars are contained in last year's Report. A long investigation has recently been going on at the Reichsanstalt for the verification of the ohm, which has just been completed. The other investigations which are now going on may be summarised as follows (these are experiments of research only):—In the Thermal Section there is going on now the determination of the expansion of water; the density of steam at temperatures between 100deg. and 500deg. centigrade; the alteration in the elasticity of metals and of alloys under different temperatures; investigations in connection with platinum thermometers, and also in the methods of the suspension of galvanometers so as to be free from vibration; the continued preparation of a large splendid hydrostatic weighing machine; investigations into high temperatures and into the use of quicksilver thermometers; the comparison between standard quicksilver thermometers in both the first and the second divisions; work with the Fizean-Abbe-Dilatometer; and the determination of the melting-point of certain substances, viz., ammonia, toluene, methyl formate, carbon bi-sulphide, ether, and ethyl bromide. Then in the electrical section they are continuing the investigations into normal elements, such as the cadmium sulphate element, the relation between the Clark and the cadmium element, the determination of the temperature co-efficient of the Clark element, the determination of certain points in connection with the Helmholtz electro dynamometer. Perhaps it is not worth reading all of them; but there are twenty-five different investigations going on in the first division.

9. Perhaps that is a sufficient sample to give us an idea?—It will not take a minute to refer to some of the others. In the Optical Section there are investigations into the laws of radiation in dark bodies; investigations into the variation of energy in the spectrum, as shown in different forms of bolometers; and so on. These are all investigations now going on in the First Division, that is in pure research. In the Second Division the Präzisions Mechanik Laboratory had last year about 200 objects to be tested; those were partly for the Reichsanstalt itself (First Division), and partly for the public.

10. (*Mr. Chalmers.*) Do you happen to know how many were for the public out of that 200?—I am afraid I did not put it down, but the Report will tell you.

11. (*Dr. Thorpe.*) All that is contained in the Official Reports, is it not?—It is all contained in the Official Report, which is very complete, and gives you full particulars of everything. These are classed as standard measures of precision and scientific investigations for both departments of the Reichsanstalt; rougher measurements of instruments, etc., for both departments; investigations on the extension of materials at different temperatures; tests of gyrometers; examination and attestation of tuning-forks; and investigations into the effect of alterations of dimensions in tempered steel which were sent in by the public for examination. In the Electrical-Magnetic Section there were 117 meters tested, and of meters for direct currents and intensity 80 were tested from 15 different manufacturers, and several others were alternate current meters. Various accumulators also were tested, and various galvanic elements were tested. The particulars were all given very fully in the Report. Last year the preparation of the electro-technical laboratory and the installation of high tension batteries and transformers largely absorbed the work of the department. Then there were investigations into the temperature coefficient of the Clark element, and the determination of electro-motive force at low temperatures. About 120 specimens were tested for conductivity, 13 specimens submitted by different tramways and electrical railways were tested for insulation, and 123 specimens were tested for resistance, of which 23 only contained 386 separate parts. The several materials which were tested for resistance are given as manganin, konstantan, patentnickel, and platinsilber. The applications from abroad for testing were as follows:—19 from America, 10 from England, 8 from Austria-Hungary, 5 from Italy, 2 from Denmark, and one from Russia. There were in addition 13 special apparatus tested for manufacturers, also various apparatus for the Reichsanstalt—those were apparatus of a peculiar construction. There was also necessary work done in connection with the annual comparisons and verifications of various apparatus for measurement belonging to the establishment itself; and those details are all given in the Report. In the magnetic section there were 56 specimens tested for magnetic qualities, the results of which occupy several pages in the Report. In the heat and pressure section there were tested 14,062 thermometers, 272 apparatus for testing the flashing point of petroleum, 4,230 safety valve apparatus, 10 manometers, 27 barometers, 34 Le Chatelier thermo-elements, and about 30 miscellaneous apparatus. Of the thermometers 12,390 were medical and about 500 chemical and other thermometers for temperatures up to 300deg. and 550deg. centigrade, 17 thermometers were for investigations below 0deg. centigrade, so that they have a range much above and below what Kew has. There were other materials and apparatus submitted, the results of which are also shown in the Report. Then there were a large number of investigations in the optical section. There were 287 Hefner lamps tested for the Standard of light, 330 glow lamps, 6 arc lamps, and 108 specimens of material for incandescent gas light, besides about 50 specimens of various apparatus for gas, petroleum and acetylene, &c. An important arrangement in this department is the production of a simple and practical method of measuring the candle-power of incandescent or arc lamps whether used in houses or in streets, and either horizontally or at an angle by Professors Brodhun and Liebenthal. I have no doubt that is known to Mr. Thorpe and Professor Rücker. This section has made investigations into the construction and testing of saccharimeters. Another enquiry which forms a large branch of what they have to do was into the influence of temperature on focal distance by Professors Lummer and Brodhun. The chemical section has carried out various investigations which are all included in the Report. The workshops have been largely occupied with the work of installation of the several departments of the Reichsanstalt in the new building. I have not got the cost of the maintenance of each division separately, but the combined cost of the two divisions is about 172,000 marks for salaries, wages and remuneration of the *personnel*. This is exclusive of the cost of maintenance of buildings, of machinery, of materials used in research, and analogous matters.

12. (*Chairman.*) Who says what you are reading? Is that a report?—No; I am reading from notes which I made.

13. Notes made by yourself?—Yes; notes which I made at Berlin the other day. You may say roughly that the second division costs between 90,000 and 100,000 marks. The receipts for testing from the public in the

second division has been a yearly increasing quantity. They amounted in 1889-90 to about 8,000 marks, but last year they reached about 30,000 marks, or, say, nearly one-third of the annual cost of the Second division. Of this sum 16,000 marks was for testing thermometers, and the remainder was for testing in the electrical, the optical, and the other divisions. Then I have got a list of the *personnel* attached to the Reichsanstalt to show you both its extent, and the subjects it takes up. There are altogether between 70 and 80 persons employed. The Thermal Laboratory employs Dr. Thiesen, Dr. Gumlich, Dr. Scheel, and Dr. Orlich. The Electrical Laboratory employs Dr. Jaeger; the Optical Laboratory, Professor Lummer, Dr. Gumlich, and Dr. Kurlbaum. Under the president, Dr. Kohlrausch, there is Dr. Holborn as a technical assistant.

14. (*Sir Courtenay Boyle.*) Might we take it that there are 70 able men employed. Is it necessary to read all the names?—I was just mentioning the principal ones.

15. (*Chairman.*) Can you classify them at all into those who are in a sense chiefs, and those who are subordinates?—Dr. Kohlrausch is at the head of the whole of the Reichsanstalt, and he is Director of the First division; in that division under him there are Dr. Thiesen, who has charge of one department, Dr. Jaeger, Dr. Lummer, Dr. Brodhun, and Professor Pringsheim—those are all what they call fellows.

16. (*Dr. Thorpe.*) They are persons connected with the sub-sections of Division I.?—Those are in the sub-sections of Division I., and they are all people at the head of particular departments of research, or arrangements for research. Then Division II. is under the charge of Professor Hagen, who is Director, and he has under him Dr. Lindeck, Professor Feussner, Professor Wiebe, and others. I could hand you in the list of names if it would be of any use to you.

17. (*Chairman.*) We are more concerned with the number. Does the number 80 which you mentioned include everybody employed?—The 80 would include everybody; workmen as well as the scientific staff and voluntary workers at research. Seventy is about the usual number, but then there are extra assistants brought in now and then into the workshops and places of that sort. The Report shows everything. They are all classified under different heads. You will see that there is a glass-blower in one of them, and that there are seven artizans working in one division of the workshops, and so many in each of the others.

18. Can you give us any general impression that you have formed as to the value of the work done and the efficiency of the organisation?—Yes; I have handed in plans showing you what the Reichsanstalt is. Those plans show you that it is a large establishment, and I think quite as large as is wanted at present; indeed, I think it is not quite fully occupied just now. The Reichsanstalt is in the first place a department for pure research, and is now no doubt, as I have said, carrying on a number of delicate investigations. In the second place it has been formed for the purpose of affording to students and manufacturers opportunities for comparing the delicate standards in use in their own workshops with a reliable standard, as well as affording a reliable scientific examination of the results of new methods of construction, and of new forms of scientific instruments. An establishment of this nature, in my view, is of the highest importance in developing the industrial progress of the country. I have always regretted that the British Government when it handed over the beer money to the County Councils did not keep a small percentage of it to apply to an establishment which would have afforded to our industries all over the country good standards for different classes of work, and which would have been a sort of object lesson to those County Councils as to what really technical education and progress mean. The beer money is given by my County Council in Worcestershire chiefly to dairying and hedging, and partly to an art school. It gives £1,000 a year to an art school at Kidderminster which teaches freehand drawing chiefly. I think the money they have got has been thoroughly wasted in my county. Formerly our progress in machinery was due to accuracy of measurement, and that was a class of work which could be done, as Whitworth showed, by an educated eye and an educated touch. But as we advanced in the application of science to industry we required accuracy to be carried into matters which cannot be so measured. For instance, in electricity we require a measurement of the different degrees of conductivity of metals under varying conditions and at different temperatures, and in different states of purity; those are things which really require very considerable care in the investigation. Take glass: we use glass for optical purposes and for thermometers, but the character of the glass for each is entirely different, and requires really different conditions. The Germans by their researches have now, I believe, got the absolute market for all optical glass. In the more delicate researches which the physical, chemical, and electrical student undertakes, he requires a ready means of access to standards to enable him to compare his work with that of others.

19. (*Sir Courtenay Boyle.*) By standards there, do you mean standards of materials, standards of glass and steel, and so on?—Standards of measurement, standards of materials, and standards of progress too. So far as ordinary thermometers and barometers and aneroids are concerned Kew affords opportunities for testing them; but Kew, for want of means, has not yet arranged for full tests of those thermometers whose ranges are very high, nor does it possess appliances or a staff adequate to extend its operations of examination and verification to other important industrial matters. Kew is placed physically in a far more advantageous position for standardizing and for research than the Reichsanstalt. The Reichsanstalt is not far removed from roads, it is surrounded by roads along which heavy traffic passes, and all the professors told me that, notwithstanding the enormous expense which has been incurred in the foundations, they all suffer in their more delicate experiments from vibrations, and that they can only carry on some of the most delicate experiments after midnight and before the traffic is resumed in the morning, and that although they have got a block of concrete about six feet thick under the whole building, entirely separated from all the surrounding parts, and the whole structure is built with the utmost care upon this block. My view is that if Great Britain is to retain its industrial supremacy we must have accurate standards for comparison available to our research students and our manufacturers. I am certain that if you had them our manufacturers would gradually become very much more qualified for advancing our manufacturing industry than they now are. But it is also certain that you cannot separate a certain amount of research from a standardizing department. A person who compares the products of a manufacturer does so upon certain lines which have been laid down by a preliminary scientific investigation. If you take a simple question of the dilatation of a bar of iron at certain temperatures, the person who tests certain bars furnished to him finds that they do not all expand or contract uniformly in their different parts, and the question why that is so is a matter for further research. This is the simplest form, I think, that I could put it to you, and I am putting it in that simplest form in order to show that you must have a certain amount of research attached to a standardizing department. This principle will go through all progress. Whatever standard you adopt in each department of science for the more delicate measurements you will find that some further research will continually be required to meet the case of some special variation. This has been the principle upon which the Reichsanstalt was founded. The First Division is devoted to research which affords a basis for perfecting the standards provided in the Second Division for assisting German industries; but whilst for the advancement of our knowledge in the higher classes of investigation a special department of research is necessary, my recent examination of the Reichsanstalt convinced me that a moderate department of research attached to the Second Division would be able, as a general rule, to supply the necessary research we require in this country to keep up the efficiency of the Standardizing Department. What I would advocate would be an extension of Kew in the direction of the Second Division of the Reichsanstalt, with such auxiliary research in the establishment itself as may be found necessary. You must have some research. This suggestion implies that each branch of science in Kew should be placed under the supervision of a fully competent man in his particular branch of science, and that the general supervision should be placed under a first-class man of recognised scientific position. That is the conclusion that I have arrived at. In respect to pure research, there are many matters of pure research which are being done in Berlin, and it, therefore, would not be necessary to repeat them over here, and others are also being done in Paris, and it would not be, therefore, necessary to repeat those over here either; but we do want a department for giving adequate standards to all our scientific people, and to all our scientific manufacturers; by scientific manufacturers I mean in every branch of manufacture. Such an establishment, I believe, could not be better maintained than by increasing Kew, and keeping it under the Royal Society as it is now, but under a Board of Visitors

Sir Douglas [illegible], K.C.B., F.R.S.

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nominated partly by the Government, and partly by the Royal Society, who would practically take very much the position which the Curatorium takes in the Reichsanstalt. Kohlrausch submits every year to this curatorium a statement of everything that has been done during the year; that is discussed for two or three days and criticised, and then he submits the plan for the following year. I have a copy here of what he submitted the year before last, to show the form in which it is submitted. Everything that is done in the succeeding year, except, of course, the standardizing of instruments, everything partaking of the nature of research, is all criticised by this curatorium before it is initiated; but the control of the management, and everything of that sort, must rest in the hands of the person who is at the head of it, and, therefore, in that person you require a first-rate man.

20. (*Chairman.*) Are you satisfied with the work done at Kew so far as it goes?—I think it is very good.

21. Your view, I think, comes pretty much to this: that you would like to see that work extended and developed?—I should like to see Kew extended. Take the thermometers for instance; they do nearly twice as many of the ordinary medical thermometers and thermometers of that sort at Kew as they do in the Reichsanstalt, and they do them in a place about the size of this room, I should say; at all events, the whole of Kew together or of the principal standardising part, I think, would go into half this house; whereas the Reichsanstalt for the same thing would take I do not know how many huge apartments and grand staircases. Therefore, Kew is a far more economically managed establishment, but then you see it has not been done at the Government expense; it has been done at the expense of individuals.

22. Do you think that what is necessary in this country might be done more economically on the lines of developing Kew than by establishing some great independent institution?—I have not the slightest doubt about it; I think it might be done, and admirably done, by extending Kew. Kew occupies a good position; it is away from the railways—it may be a little shaken by the South-Western Railway perhaps occasionally, but still, it is a very long way off from the railway compared with what the Reichsanstalt is from the tramways around it, and at Kew they ought to be fairly free from vibration. There is plenty of space there, and nobody wants the space there except to play golf on, and they could easily give an acre or two of that without the golf ground being very much injured.

23. There is no doubt in your own mind of the importance of the class of work that is done at the Berlin Institution?—There is not the slightest doubt that it is of the highest importance and the highest value—all of it. You will see if you look into the Report the immense importance which the researches they undertake have, every one of them, in developing science.

24. Do you think that the comparative neglect of such work here has stood in our way?—I think the manner in which the neglect of that work has chiefly stood in the way here is that it is responsible for our manufacturers not caring for science in the same way that they do in Germany.

25. (*Mr. Chalmers.*) Would you say that of Manchester?—Yes.

26. Would you?—I would say so to a great extent; some of them care for it, but in the general progress of the nation they do not. Take the chemical works; how very few of them have a large number of chemical assistants attached to them permanently, as chemical manufacturers in Germany have, merely for the purposes of research. You have two chemists on the Committee who can tell you, but I have been told by Professor Armstrong and many chemists that they really have a great difficulty in finding places for their people who have been studying chemistry under them, because the manufacturers do not realise the enormous importance of having men attached to them solely for the purpose of developing research in their particular branch of industry.

27. (*Chairman.*) Have you any view as to the connection of what is now done by the Board of Trade in its Standard Department, electrical and other, with such an institution as you would wish to see Kew developed into?—Yes.

28. Are we to gather that it is your opinion that what is now done by the Board of Trade is inadequate?—I think the electrical part of it requires developing on the lines of the establishment I have been speaking of.

29. (*Sir Courtenay Boyle.*) Does that apply to supply meters, as well as to ammeters and voltmeters?—Yes, it certainly applies to supply meters.

30. The Reichsanstalt surely would not verify an individual consumer's supply meter?—No, not an individual's meter, but it verifies the meter of a manufacturer which is going to be adopted, and gives it a status as a standard instrument, and after such a meter has been adopted, then, of course, it can be used as a means of testing the efficiency of meters used by individuals.

31. We must be careful or we shall get into a little ambiguity about "verification." The word "verification" is used in our Acts of Parliament and Provisional Orders as meaning the proof that a consumer's meter is up to the sample of the standard; and that seems to be the duty, not of any central body like Kew, but of some local authority?—Yes, I quite agree with that. After a meter has been given to a consumer, and certified to be able to measure certain things, of course the question whether that individual meter measures accurately or not would be a matter for a local authority, as is the case with weights and measures.

32. Exactly, it is a weight and measure then?—It becomes a weight and measure then.

33. Having got your actual standard of supply meter, the comparison of the local meters with that standard is a duty which need not be entrusted to the central authority, but may be entrusted to the local authority?—I think it would necessarily be entrusted to the local authority.

34. (*Dr. Thorpe.*) When did you personally examine the Reichsanstalt, in what year?—I examined it in 1895, and I examined it again the week before last.

35. Did Dr. Hagen tell you that they contemplated amalgamating practically with the standards commission of weights and measures?—They did not tell me they were going to amalgamate with it, but they told me that the Weights and Measures Department (the *Normal-Aichamts Commission*) had bought some land close to the Siemens and Halske works, opposite the Reichsanstalt, on the other side of the road.

36. The idea being that the two institutions should work in co-operation?—That Dr. Kohlrausch did not say. I asked him that and he said that was not at all settled, or he rather implied that they were not to be united; but that when desired the Reichsanstalt would afford assistance in matters of research to the Weights and Measures Department. I was staying with him, and I asked him all about these things as much as I could. He did not say positively it was not, but at all events he left the impression on my mind that it is not to be connected in management or in control, but that it is merely to be placed near it. I did not see the Head of the Weights and Measures Department, I only saw the Reichsanstalt people and other physical professors in Berlin.

37. (*Mr. Siemens.*) You have spoken all the time, I think, as if the Reichsanstalt occupied itself exclusively with standards?—No, I spoke of investigations.

38. In the latter part of your evidence you put great stress on standards and standardising, but the other work which the Reichsanstalt does is also important?—Yes, in the latter part of my evidence I was saying, or at least I thought I was, that what I consider very important for us in this country, is to perfect out standardising arrangements, and that I did not see that we need go into the whole of the classes of research which are undertaken in this first division of the Reichsanstalt.

39. I am thinking of the second section exclusively; the second section is an undertaking which also investigates the qualities of materials and such things, and that is an important branch of the work; but I believe it is not the intention of the Reichsanstalt to interfere in any way with weights and measures—with what is called in Germany the Aich Amt—I do not know what is the proper technical expression here—and with supplying meters?—I went into that with Dr. Kohlrausch, and I said, "Now tell me, how are you fulfilling the various conditions in regard to the inquiries into the nature of materials?" He said, "That is done in the second division. There are magnetic observations and investigations on resistances and on conductivity, on the duration of glow lamps, on thermal expansion, on the specific heat of solutions and on incandescent materials." That is under A. Then under B, he said there was not very much going on now, but under C there were numerous applications for the verification of the Standard quality of Abel's apparatus to determine the flashing point of petroleum, the standardizing of saccharimeters, photometric apparatus, thermometer proving apparatus, etc.

40. You said that the Reichsanstalt was so very large, but have they not got rooms built for future extensions?—Yes, undoubtedly.

41. A good many of the rooms are empty at present?—There are not many persons at present in some of the rooms.

42. It has been built on such a large scale in order to

provide for future extensions, has it not?—I have no doubt that in the First Division they are pretty well filled with investigations, but in the Second Division there is a large number of rooms not yet occupied.

43. But that has only just been finished, I believe?—It was only finished last year or this year.

44. (*Dr. Thorpe.*) I think it is the fact that there are a considerable number of rooms for which there is no obvious or at all events immediate purpose?—That is so, there are a certain number of rooms not occupied. I will not say a very large number in proportion to the size of the building because, although perhaps there are four or five rooms, you see it is a very big building.

45. (*Mr. Rücker.*) You were good enough to give us the operations which were carried out in the First Department; supposing there was an institution in which there was not this clearly defined line of demarcation between the two Departments, many of those operations would really have to be carried out in the Second Department; for instance, measurements of the higher temperatures of platinum thermometers which are largely of industrial importance would have to be carried out in the Second Department if there was not a First Department to carry them out in?—Yes, what I wanted to say was that some research must accompany efficient standardizing, and that I thought a Second Department—but that is very much an argument for you—would, with a moderate division for research in those various matters, be all that would be wanted in this country—not for the larger ideas that Helmholtz had.

Sir Douglas Galton, K.C.B., F.R.S. 18 October 1897.

46. (*Chairman.*) Have you anything more to lay before us?—No, I have nothing else.

Wednesday, 20th October, 1897.

PRESENT:

The Lord Rayleigh, D.C.L., F.R.S. (*Chairman.*)

Sir Courtenay Boyle, K.C.B.
Sir John Wolfe Barry, K.C.B., F.R.S.
Mr. W. C. Roberts-Austen, C.B., F.R.S.
Mr. Robert Chalmers.
Mr. A. W. Rücker, D.Sc., F.R.S.
Dr. T. E. Thorpe, F.R.S.

Mr. L. Blaikie, *Secretary.*

Sir Courtenay Boyle, K.C.B., a Member of the Committee, Examined.

Sir Courtenay Boyle, K.C.B. 20 October 1897.

47. (*Chairman.*) We understand that you have a statement to make to the Committee in reference to the legal position of the Board of Trade in connection with the matters referred to us?—I have prepared a short statement of the position of the Board of Trade as bearing upon the question of the relation of the State to standards, so far as those standards have to do with weights and measures. We had admission after admission from Sir Douglas Galton the other day that weights and measures did not come into the consideration of ourselves, as a Committee, or of the German Reichsanstalt, but still I think it would be of convenience to the Committee if they understood exactly what is the position of the State as regards weights and measures, and, therefore, I have prepared a very short statement. In 1862 the House of Commons appointed a Select Committee "to consider the practicability of adopting a simple and uniform system of weights and measures with a view not only to the benefit of our internal trade, but to facilitate our trade and intercourse with foreign countries." Their principal recommendations were (1) that the metric system should be rendered legal, and (2) that a department of weights and measures should be established in connection with the Board of Trade, to which should be entrusted the conservation and verification of the standards and the superintendence of inspectors. It was in order to deal with the absence of any comprehensive system of inspection of local standards that the second of these recommendations—leaving out the metric system for a moment, which has only just been dealt with—was given effect to by the passing in 1866 of the Standards of Weight, Measures and Coinage Act of that year. That set up a department of the Board of Trade to be called the Standard Weights and Measures Department, and there was to be an officer at the head of that department called the Warden of the Standards. Another section provided for the transfer to the Board of Trade of the custody of the Imperial and Secondary Standards, and other apparatus deposited in the office of the Exchequer, or in the custody of the Comptroller-General of the Exchequer, and for the transfer to the Board of Trade of all powers and duties in relation to standards of weights and measures which were vested in the Treasury or the Comptroller-General of the Exchequer. In 1868 a Royal Commission was appointed to inquire into the condition of the Board of Trade Standards, and for various other purposes. The Commissioners made several reports between then and 1870, among others, "That it is expedient that a bill be brought into Parliament by the Government at the earliest period to amend and consolidate the laws relating to weights and measures, and the standards of weight and measure, and to the sale of gas, and for carrying into effect the preceding recommendations." In 1878 the Weights and Measures Act of that year was passed. It was mainly a consolidation Act, but among other things it amended the law in various particulars, and it transferred to the Board of Trade the powers and duties vested in the Warden of the Standards. That produces rather a curious result. In 1877 there was a minute of the Board of Trade, appointing the Secretary of the Board of Trade to be Warden of the Standards *ex officio* and *in perpetuo*; but by the Act of 1878 his duties were transferred to the Board of Trade. So the duties of the Secretary of the Board of Trade were transferred to the Board of Trade, which is a most amusing state of affairs; and now I cannot tell you whether I am Warden of the Standards because I am Secretary of the Board of Trade, or whether as Secretary of the Board of Trade I am advising as to the discharge of the duties of Warden of the Standards. That is, rather, a nice point, which those interested in archæology will be able to investigate. By the same minute Mr. Chaney was appointed Officer in Charge of the Standards Department. Then the Weights and Measures Act, 1889, imposed fresh duties upon the Board of Trade, and gave them fresh powers, but did not alter the constitution of the Department. I think it would be for the convenience of the Committee if I gave a short account of the powers which we have, which are vested in us by the Legislature. By the Sale of Gas Act, 1859, provision was made for the making and depositing with the Comptroller-General of the Exchequer of models of gasholders for testing the measurement and registration of gas meters, and for the verification and stamping at the Exchequer of copies of such models for the use of Justices of the Peace, or Town Councils who have adopted the provisions of the Act. By the Act of 1878, which I have just referred to, those powers were transferred to the Board of Trade. In 1870 the Coinage Act transferred to the Board of Trade the custody of the trial plates of gold and silver used for determining the justness of the gold and silver coins of the realm. These plates were formerly in the custody of the Exchequer, and subsequently of the Treasury, but when the office of Master of the Mint was vested in the Chancellor of the Exchequer, it was held desirable that the Chancellor of the Exchequer should not examine his own work; in other words, that the Chancellor of the Exchequer, who was Master of the Mint, should not test the action of the Master of the Mint in making the coins, and, in consequence, the duties of keeping the standards of test were transferred to the Board of Trade. As the Committee are aware, the trial of the pyx is now conducted under special arrangements, and one of the members of this Committee is examined most carefully every year by a Committee of the Goldsmiths' Company, who do their work most admirably, and I need not tell you that they generally report very favourably of the excellent action of the Mint.

48. Is that under the Board of Trade?—We look the

Sir Courtenay Boyle, K.C.B. 30 October 1897.

trial plates, and we have to produce them every year at the trial of the pyx. Either I attend myself, or Mr. Chaney attends every year, and by request of the Queen's Remembrancer produces these trial plates of gold and silver, from which are taken scrapings which are made the test of the assay of a select number of coins.

49. I meant, is the trial carried out under the authority of the Board of Trade?—No, the trial is not under the authority of the Board of Trade. A special arrangement is made for the trial; a jury is struck, and the Queen's Remembrancer issues instructions to them, and they make their report.

50. (*Mr. Chalmers.*) At the instance of the Treasury, as you are aware, under the Act of 1870?—It is at the instance of the Treasury, but we keep the standards in order that that very danger might be avoided which a former Chancellor of the Exchequer in Parliament alluded to when he said that the Chancellor of the Exchequer should not keep the test of his own work. You will find that Mr. Lowe, when he was Chancellor of the Exchequer, in a debate in the House of Commons, pointed that out. Under the Act of 1878 we have the duty of making copies of the Imperial standards of measure and weight for deposit at the Board of Trade; we have the duty of restoring the Imperial, Parliamentary, and Secondary Standards in case of loss or injury; the construction, if required, and verification of new denominations of standards being equivalent to, or multiples, or aliquot parts of Imperial weights and measures; we have also the powers and duties relative to standards of weights and measures heretofore vested in the Treasury or the Exchequer, and the duty of conducting such comparisons, verifications, and other operations with reference to standards of measure and weight in aid of scientific research, or otherwise, as we may think expedient. By other sections we have the custody of the Imperial and Board of Trade standards, and the custody of copies of the Imperial standards referred to in a previous section; we have the duty of comparing at stated intervals the Parliamentary copies of standards with each other and with the Imperial standards, and we have the duty of comparing the Board of Trade standards with the Parliamentary copies, and, if necessary, adjusting or renewing them. Possibly some of the Committee are aware that the allocation of some of the standards is most carefully selected; for instance, one copy of the standard yard is immured in a wall of the House of Commons, in a stone on that staircase that leads up to the Committee Rooms; that is taken out every fifteen years by the Speaker with more or less ceremony, and is verified, and is then put back again. That is one copy of the yard; another copy is deposited, I think, with the British Association, and one at the Standards Department near here. Then we have the duty of comparing, verifying, re-verifying, and stamping local standards, and of granting indentures as evidence of such verification, and of keeping accounts of all local standards verified or re-verified; we have the duty of verifying and stamping coin weights; and we have the duty of approving bye-laws as to local verifications of standards made by local authorities. Under the Petroleum Act, 1879, we have the duty of comparing with the model deposited with us, and of verifying, and, if correct, stamping such apparatus to be used for testing the flashing point of petroleum, as is submitted to us. We have further powers under the Act of 1889; for instance, we have power to deposit with an Inspector of Weights and Measures copies of metric standards in the custody of the Department, and to cause the metric weights and measures to be verified with such copies. We have power, as some of us know, to make new denominations of standards for the measurement of electricity, temperature, pressure, or gravities. Under that last section the Board of Trade, a little while ago, did make new denominations of electrical standards, namely, the ohm, the ampère, and the volt; Lord Rayleigh was a member of the Committee which dealt with that. Then we have power to approve of the material and form of working standards for the use of officers of local authorities, and we have power to take fees on the comparison and verification of weights and measures, not being standards, for the use of a local authority, or coin weights, and also fees on testing weighing and measuring instruments. Then we have certain powers as regards byelaws. Under the Act of 1897, the Act of this Session, we have the power to make Board of Trade metric standards. Those exhaust the powers of the Board of Trade generally. You will see that we have purely for commercial reasons, and not for scientific reasons, I submit, but anyhow, more for commercial reasons than for scientific reasons—the duty of seeing to the verification of standards. By standards, in that sense, I mean standards of weights and measures. That duty is clearly imposed upon the Board of Trade, and to change that would require a very considerable alteration in our commercial system, and a very considerable alteration in our local systems of weights and measures. But that only applies to standards of weights and standards of measures. In our electrical standardizing laboratory we have gone a little bit beyond that. In June, 1889, a joint deputation from the London Chamber of Commerce and the Institution of Electrical Engineers came to Sir Michael Hicks-Beach to urge the Government to establish an electrical standardizing laboratory. They represented that the supply of electrical energy could not be efficiently carried out under statutory powers without the provision of some means for standardizing meters and other instruments used in connection with the supply. At that moment I do not think it was clearly defined what they meant, or what we meant, by meters. The trade was much hampered by the uncertainty and the want of generally recognised standards of electrical quantities. They represented that the standards should be maintained by the Board of Trade, and that a laboratory should be established where measurements of the various electrical quantities could be effected, and whence certificates could be issued which could be generally accepted. They pointed out that manufacturers in this country were at a considerable disadvantage as compared with foreigners, who could have their instruments tested at Berlin and Paris, and obtain the necessary certificates. As the result of the representations of this Committee, the Electrical Standards Committee was appointed, of which I had the honour to be Chairman, and Lord Rayleigh was kind enough to act as a member of it. Some of us remember that in consequence of that an order in Council was passed defining the ohm, the ampère, and the volt, of which, up to then, there was no legal standard. Now having got these standards, we have gone a little bit further, though I have seen certain objections to it. We have undertaken to receive for examination and testing electrical instruments intended—and this goes a little beyond our ordinary functions—for the measurement of pressure, current, power, quantity, energy, or resistance. That includes the testing of ordinary electrical instruments for manufacturers and the testing of special instruments to be used as sub-standards by local authorities and others; but we do not include the testing of individual meters with the view to a certification for their use in connection with supply. We approve a pattern of supply meter; in fact, nobody is allowed to charge by meter in London unless they employ a meter of a pattern approved by the Board of Trade. I am sorry that we have approved very few patterns up to now, and that, consequently, that section is not carried out in its entirety. We have approved the Schallenberger Meter and two or three others. Major Cardew will tell you what they are; but having approved the pattern, the approval of the meter is a matter for the local inspector and not for ourselves. Now I think I have explained our position, and I shall be very glad to answer any question which any of my colleagues think necessary.

51. (*Chairman.*) You have referred to the case of weights and measures, and to the case of electrical standards; I do not know whether you could tell us how the case of temperature stands?—We have nothing to do with that; we are not concerned with it. Under the Petroleum Act we have power, as read out just now, to verify standards for determining the flashing point; but temperature we have nothing to do with.

52. But the flashing point could only be defined by means of temperature?—I know.

53. And if the temperature itself is not defined, what is done?—It is very near defining temperature, but I do not think we could define temperature. As you know, our standard ohm had reference to temperature. As to temperature itself we are silent, and I submit, I think I am right in saying, powerless.

54. (*Dr. Thorpe.*) What steps are taken then as to the verification of instruments which are used by you with reference to temperature; as, for example, any thermometers which may be used by you?—Actually what is done you will get from Mr. Chaney in a minute. My impression is that, as regards any testing of the temperature or means of ascertaining temperature, we take what is brought to us and do the best we can. I do not think we have any powers in reference to it. Of course, you will hear from Mr. Chaney presently that temperature enters very largely into all his verifications; but I think he has got to take his temperature, and I do not think he can make it himself.

55. (*Chairman.*) It seems to introduce rather an undefined element into what, in words, would have an appearance of precision; for instance, if the flashing point of petroleum is not to be below so and so, defined in Fahrenheit degrees or in Centigrade degrees, as soon as such a question is brought to the issue an actual thermometer must be used, and the question will then at once arise——Which?

56. Yes, and is the thermometer to be trusted?—Is the thermometer reliable? Upon that I should think we should take the best advice that we can; but I would rather you would put the question to Mr. Chaney—what he would do under those circumstances? My impression is that legally he has no power to verify a thermometer or to standardize a thermometer. He may do it for his own guidance, and for his own use in verifying other standards, but *qua* thermometer I do not think he has got any power to verify it.

57. (*Mr. Roberts-Austen.*) The standard trial plates are not made by the Board of Trade, or even verified by them, are they? They are simply kept by the Board?—They are kept by the Board and they are replaced by the Board.

58. But they are not made by them or verified?—We have to compare the Board of Trade standards with the Parliamentary copies, and, if necessary, adjust or renew them.

59. That is weight, but I am speaking of the fineness now?—Certainly not that; we only keep the plates, we do not make them.

60. What provision is made for the training of your officers; are they scientific men or are they trained in the Department itself?—We have Mr. Chaney, an officer in whom we have great confidence, at the head of the Department, and we try to provide him with gradually trained men, who may or may not qualify to take his place when the vacancy is created; we try to train up young men under him.

61. In the Department?—In the Department.

62. (*Mr. Rücker.*) You have told us that you had a committee of scientific experts, if I may use the phrase, to assist you in starting the electrical laboratory; is there any machinery by which the work of that laboratory is kept under scientific supervision other than that of the head of the laboratory himself?—No. The head of the laboratory himself is instructed to lose no opportunity of consulting scientific electricians in reference to their procedure, and of taking their advice in that way. But he is solely responsible, and there is no Committee of Advice.

63. That is to say at the Standards Office as well as at the Electrical Office there is no mechanism similar to that of Greenwich, where there is a board of visitors?—There is no advisory committee. Practically we do our utmost to consult those who can best advise us, but there is no set-up advisory committee.

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64. I will not ask you many questions on matters of opinion, because we shall be discussing opinions afterwards; but do you think that it would strengthen the position of these Departments if there were a Board somewhat similar to the Board of Visitors at Greenwich?—That is a very moot question. Personally I am in favour of advisory committees, but if we had advisory committees at the Board of Trade we should have them by dozens and by twenties upon the various points we have to deal with. It may be argued that to set up a series of advisory committees with *quasi* statutory powers would weaken the responsibility to Parliament of the Department—that it would enable the Department to put off its responsibility on to those committees, and, therefore, would weaken the control of Parliament.

65. If all the standards, both electrical and those for weights and measures, could be brought under one advisory committee do you think there would be any advantage in that?—No; I should think there would be a certain amount of divergence. I should think the electrical standards stood on a footing by themselves. That is my opinion. I do not say it is worth much. But the question of advisory committees is a very broad one, and has to be regarded in a great many aspects.

66. (*Chairman.*) Can you give us facts as to the magnitude of the staff employed under the Board of Trade at the Standards Department?—I could put that in; I have not got it on the papers that I have with me.

67. I think we should like to have it.—Very well, I will supply that, but I can tell the Committee it is not very large.

(*Vide* Appendix.)

68. (*Mr. Chalmers.*) I think you have got fees in connection with this?—Yes.

69. What sort of fees do you charge?—We have fees as regards electrical standards.

70. Not as regards weights and measures?—No.

71. Then perhaps as regards electrical standards in your return you would put in the fees and the number of applications?—Yes. We have only just established a system of fees. We had been doing it for nothing, but perfectly rightly we were rather hauled over the coals for doing it for nothing, and we have lately set up a system of fees.

Mr. Henry J. Chaney, called; and Examined.

72. (*Chairman.*) I think you are in charge of the Standards Department of the Board of Trade?—Yes.

Mr. H. J. Chaney.

73. What is your precise official title?—Superintendent of Weights and Measures.

74. The Committee would wish to hear from you anything that you may have to say as to the work carried out in the Standards Department; in the first place, what do you regard as your primary duty at the Standards Department?—The preservation of standards, their construction and restoration, and the verification of copies of those standards with the primary standards. (List of physical standards handed in; *vide* Appendix.)

75. Does that mean copies brought to you by the public?—Yes; by local authorities and by manufacturers, or for the purposes of science.

76. Do you include in that the construction of standards as well as their preservation?—Yes.

77. What precisely does that imply?—If the present standards were lost or injured, and had to be restored, the Board of Trade would have fresh standards constructed under the Weights and Measures Act of 1879; and those fresh standards when constructed would be legalised by an Order in Council, and would take the place of the injured or lost standards.

78. In the case of no accident happening to the existing standards, would there be any work to be done coming under this head of the construction of standards?—Yes; there would be the construction of new denominations of standards.

79. Can you give us examples of that?—Yes; secondary standards to take the place of the primary standards which are only referred to on rare occasions. In 1886 new secondary standards of the yard and pound were constructed under the direction of the Board of Trade, and are the actual standards representing the Imperial fundamental units now referred to at the Standards Office. Another instance is that with which I have less to do—the legalising of standards for the measurement of electricity in the year 1894.

80. Do you consider that your powers and facilities are adequate for the kind of work to which you have just been referring?—Yes.

81. Have you any connection with the International Bureau at Paris?—Yes. This country is one of the twenty countries who joined the Metric Convention in 1884, and the Board of Trade are associated with that Bureau in the construction and verification of standards.

82. Is there much communication passing between your Department and the International Bureau at Paris at the present time?—Yes; we take no important step as to methods of verification or of construction without reference to the Bureau. (Statement as to the Bureau handed in; *vide* Appendix.)

83. (*Sir Courtenay Boyle.*) That is, methods of the verification or construction of primary standards or secondary standards?—Yes.

84. Not of verification of local standards?—That is so.

85. (*Sir John Wolfe Barry.*) Is that confined to the Metric Standards?—Yes.

86. Not to the British Standards?—It is confined in the first place to the Metric Standards and afterwards to the inter-comparison of the British Standards with the Metric Standards.

87. (*Chairman.*) Can you give the Committee a general idea of the magnitude of the staff employed under you at the Standards Department and of the expenditure?—The staff is very small. It includes a clerical staff—four officers—two verifiers, a messenger, and the Superinten-

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dent of Weights and Measures. The cost of the Standards Department (technical expenses) is about £2,000 a year exclusive of the clerical expenses.

88. Does this include the Electrical Department?—It is exclusive of the Electrical Department.

89. May we take it that £2,000 pretty well represents the annual expenditure?—Of the Standards Department, exclusive of clerical work.

90. Does that include anything more than salaries?—Yes.

91. (*Dr. Thorpe.*) Would you kindly explain how this sum is expended?—It is expended in the technical work, partly in salaries, and partly in the maintenance and repairs of instruments, and provision of new instruments.

92. (*Chairman.*) As regards the testing and verification of instruments for physical investigations, what is the work done in your Department that would come under that description?—I have here a descriptive list of instruments, being other than Imperial and Metric Standards, which are tested by the Standards Department, which I will hand in to the Secretary if the Committee will allow me. (*Vide* Appendix.) It is divided into Gas, Gauges, Geometry, Gravities, Light, Linear Measures, and so on.

93. (*Sir Courtenay Boyle.*) Give examples of a few?—Under the head of "Gas" we have tested cubic foot bottles, experimental meters, and sulphur meters. Under "Gauges" we have tested dry measure gauges, fish-net gauges, gun-ring gauges, and wire gauges. Under "Geometry" we test instruments used by Inspectors of Weights and Measures, and under "Gravities" we have tested specific gravity bottles and hydrometers. Under the head of "Light" we test photometric measuring apparatus; that is, not the photometer in itself, but certain measuring apparatus that goes with a photometer. The photometer is the instrument used by the gas companies and local authorities in testing the illuminating power of gas. Then, in connection with Linear Measures, we verify measuring tapes and surveying rods, and under "Measures of Capacity" we have verified foreign and colonial native measures. Under the head of "Spheres" we have tested bicycle anti-friction balls and displacement spheres. Then we have also tested water-pressure gauges, balances, scale-beams, and weighing machines, assay weights, and foreign and Colonial native weights.

94. That is not an exhaustive list; it is an exemplary list?—Yes.

95. From what class of persons do these instruments principally come of which you have just now been speaking?—They come mostly from local authorities—County Councils and Borough Councils—and from manufacturers.

96. (*Mr. Roberts-Austen.*) You referred to bicycle balls; does that mean the quality or what; it is a very small thing?—It means diameter. We only test with regard to dimensions.

97. (*Chairman.*) Is that a class of instrument which you describe as for physical investigation?—No; I should hardly describe it as such.

98. Are there any verifications that you could describe as being made for purely physical investigations without regard to immediate practical use?—No; the department is not organised for research, and I take it that physical investigation involves research more or less.

99. I was referring rather to the verification of instruments intended to be used for purposes of research elsewhere.—We verify instruments intended to be used for the purposes of research to some extent. For instance, experimental gas measuring instruments of various forms.

100. (*Mr. Chalmers.*) Ordinary commercial gas meters do you mean to say?—No; different forms of gas measuring instruments either in glass or metal.

101. (*Chairman.*) Might I put my question in this form: Suppose a cathetometer were sent to you for the verification of its scale and working, would you regard it as within the province of the department to verify that?—Yes; we have verified such instruments, also specific gravity bottles, which are used in chemical research; also gauges for use in reference to the pentane standard of light; and displacement spheres for use in testing the weight of water and spirit displaced, in research with reference to hydrometers.

102. In the verification of the instruments of which you have been speaking, I presume you have regard only to the kind of accuracy demanded in practical use?—We go further than that. I have a statement here shewing the limits of accuracy within which such verifications are carried out, and it is my duty to say that they are carried out with the highest amount of accuracy.

103. (*Sir Courtenay Boyle.*) By yourself and the verifier?—It is my duty to say that.

104. You are quite right to say it, but it is done by yourself and the verifiers under you?—Yes.

105. How many verifiers have you under you?—Two.

106. What are they paid?—£104 annually, and there is also an office-keeper, who acts as mechanic at a salary of £160.

107. Do you think that they are capable of arriving at a high degree of absolute scientific accuracy?—No; they are merely mechanical officers carrying out certain directions.

108. Of yours?—Of mine, or those that I have received elsewhere. I mentioned earlier that we work in accord, for instance, with the Committee at Paris, of which I am a member, and I endeavour at the Standards Office to reproduce their methods of verification.

109. (*Chairman.*) Let us be quite clear what we are speaking of. Are you speaking of such a thing as a gas meter?—No; I am speaking of an instrument of a higher order perhaps.

110. My question related rather to the class of instruments that you had spoken of last, namely, the gas meters?—Take a cathetometer, an instrument that occasionally is used for highly accurate purposes. That instrument need not be verified by me. The verification of the linear scale of a cathetometer is a microscopic one which can be carried out by two careful men accustomed to the use of the microscope. Their results can be reduced and checked, and to that extent I would well trust those two men to verify a cathetometer.

111. It would be your practice if such an instrument were submitted to you to test it to the highest degree of accuracy that you know how to use?—Yes.

112. But there must be other cases in which you would feel that such a degree of accuracy would be superfluous and almost a waste of labour?—Yes. We have a series of scales of accuracy, if I may say so, which will appear in a paper which I hope to be allowed to hand in. We divide our work into primary and secondary work, work for manufacturers, and so on. With regard to the higher amount of accuracy, if we have a standard to verify, or an instrument to verify for a foreign Government, that Government generally sends over a committee, as happened recently in the case of Russia, when Professor Mendeléeff and Dr. Blumbach came over, and that committee worked with us in carrying out the verification work.

113. I understand you have a paper which you will put in, which will indicate the degree of accuracy aimed at in various classes of cases?—Yes.

114. Do you have applications made to you for verifications which you are unable to undertake?—Yes. We have received applications for testing steam pressure gauges. There is a demand for such work, and so far as I am aware it is not undertaken anywhere. That is not strictly physical investigation, it is work for manufacturers. Then we have received applications for the testing of water meters—that again is a practical matter; and for the verification of instruments used in testing the strengths of materials. We have on several occasions declined to undertake experiments in matters of physical investigation, because we have no staff for the purpose. We have also declined applications for the verification of standards of light, and for the testing of gas burners. There is no standard of gas burner, except in the case of the Metropolitan Gas Light Acts, under which Acts standard burners are deposited with the Board of Trade, and we verify copies of them, but only to that limited extent do we verify gas burners. We have been asked to verify hydrometers, but we decline now to undertake that work in the absence of a standard hydrometer. We have also declined applications for the verification of thermometers other than for use in the measurement of gas and the testing of petroleum or thermometers used with linear standards. We do not verify any thermometers except those used with gas measuring standards and petroleum apparatus. (Statement of applications from manufacturers, etc., handed in; *vide* Appendix.)

115. Arising out of that, may I ask what is your standard of temperature in such a case?—For gas purposes it is mainly the Centigrade scale excepting as to commercial purposes, and then it is Fahrenheit scale.

116. How are the thermometers that it would be necessary to employ actually checked?—The Board of Trade possess probably the highest standard thermometers in this country; we have four Centigrade thermometers that were issued to this country at the same time that similar standards were issued to other countries by the Metric Bureau at Paris. Those four standard thermometers have been tested, and the equivalent degree of the Fahrenheit scale by means of those Centigrade standards has been carefully determined in terms of the hydro-

gen scale. We have in this country, unfortunately, no standard Fahrenheit thermometer, and hence we are obliged to fall back upon the work of the International Bureau at Paris.

117. Which relates in the first instance only to Centigrade thermometers?—Yes.

118. (*Sir Courtenay Boyle.*) Have you any statutory power either of making or of verifying, or of testing a Fahrenheit thermometer?—If the Board of Trade so think fit, we could make a standard Fahrenheit thermometer and verify copies of it for the use of local authorities. We have power under the Act of 1889.

119. (*Dr. Thorpe.*) By making a standard, do you mean simply setting up one instrument and so calling it; I mean to say, do you take a particular thermometer and say that shall be the standard thermometer; is that what you mean by a standard?—No; I do not think we should rely upon one instrument only. These instruments, of course, are liable to some change and are fragile. We should take, say, a series of four instruments, copies of those standard thermometers being deposited elsewhere, and we should legalise those four.

120. (*Chairman.*) Suppose a dispute were to arise, say, in the matter of testing the petroleum, as to the particular temperature at which it flashed, and the question were to come into a court of law, and the accuracy of your thermometers was disputed, what would be your position?—Our position, legally speaking, would not be altogether satisfactory. There is no standard of the Fahrenheit thermometer, and so we do the best we can to verify it. But I may say that in the Act of Parliament relating to the testing of petroleum there is no provision for testing the thermometer; the thermometers—and there are two used with the petroleum apparatus—come in as a part of the tests. We cannot verify the instrument and say it is correct until we have verified the two thermometers, but the Act itself does not require us to verify those thermometers, and we are only required to verify the apparatus as a whole.

121. Still that involves as part of the test the verification of the thermometers, does it not?—Yes.

122. (*Mr. Rücker.*) May I ask the exact meaning of the word "verify" as you use it? Does it mean simply referring to the arbitrary standard which you yourselves have created, or does it mean referring ultimately to the hydrogen thermometer through the International Bureau?—I think it does refer to the most accurate instrument we can have access to, because I would submit that verification means verifying the accuracy of the Abel instrument as a test of the flashing points of oil.

123. (*Chairman.*) But unless a special definition is made it is a matter of argument what is to be meant at all by an intermediate point of the thermometer coinciding neither with the freezing-point nor with the boiling-point. According to the hydrogen thermometer it would be one thing, and according to the mercury thermometer it would be another, and so on. Would there be no definite guidance as to what is meant when a temperature is spoken of in an Act of Parliament?—None; no legal guide. We have, of course, the high scientific guide of the Kew Observatory.

124. You would interpret it then to be taking advantage of the best scientific knowledge of the time?—That appears to be all we can do.

125. (*Mr. Rücker.*) If a person who was interested in the matter were to take up the position that by a temperature Fahrenheit was meant a temperature measured as at the time the Act was passed, say, 20 years ago, and that you were not at liberty to introduce modern refinements, would there be any answer to that?—No; because no one can say what the Fahrenheit thermometer was in Sheepshanks' time. The copies of the Sheepshanks thermometers which are still remaining, by which the standards of his time were verified, are no longer of any use.

126. (*Sir Courtenay Boyle.*) You would have to show, would you not, that you had got the best Fahrenheit thermometer available known to ordinary minds at the present moment, and that you had tested your flashing points by that?—Yes.

127. (*Mr. Rücker.*) Perhaps I may put it from another point of view: The glass made and used in England many years ago was such that the temperature Fahrenheit was different, to a small extent at any rate, from that given by the hydrogen thermometer?—Certainly.

128. Therefore the flashing point as given by the hydrogen thermometer would not be the same as the flashing point given by mercury thermometers at the time the Act was passed?—It would not.

129. (*Dr. Thorpe.*) I think perhaps it would conduce to clearness, at all events to a little clearness in my mind, if you would tell us exactly what you do in the case of the Abel instrument as regards thermometers. You spoke of verifying the accuracy of those thermometers. Will you tell us what steps are taken to ascertain their accuracy?—We have standard thermometers of a certain degree that have been verified at the Kew Observatory, and that have also been verified by ourselves by comparison with standards of Balfour Stewart's time and others, and also by comparison with the Centigrade standards of the present time. That is our starting point. We place two standard thermometers in a thermometer comparator, and we put the two petroleum thermometers between the two standards, and by means of a little telescope read off the heights of the mercury when in a vertical position as compared with the heights of the mercury in the two standard thermometers.

130. At more than one position?—Yes.

131. At several positions?—Yes, we are obliged to do that.

132. Would that apply throughout the whole range of the Abel thermometers?—Yes.

133. Throughout the whole range?—Throughout the whole visible range.

134. Throughout the range to which the graduations extend?—Yes; except that in some of the thermometers the graduations extend rather below the height of the cup, and we should not verify those. I should mention that these thermometers which are used for petroleum purposes are not very accurate, and that an error of half a degree Fahrenheit is often found, whereas those used for gas purposes have to be verified with much greater accuracy.

135. (*Chairman.*) What is the particular application of the thermometers for gas purposes that you have in mind?—For determining the temperature of the gas.

136. So as to measure the amount of gas that is burning?—Both as a quantitative and as a qualitative test of gas. The thermometer determines the temperature of the gas so that we may find its volume at a given temperature, say 62 degrees Fahr.

137. As a datum for finding the quantity of gas employed?—Yes.

138. May I ask whether you have thermometers sent to you for verification—accurate thermometers I mean—independent of these particular ones?—Yes; we have had such sent to us and we have declined to test them where they have been required for scientific purposes.

139. Could you give any reason for that?—We have not the means for properly testing thermometers for scientific purposes, either Centigrade or Fahrenheit, excepting for our own purposes. The testing of a thermometer for scientific purposes is a long operation, and I have not the staff to undertake such work.

140. Have you ever thought it desirable that your staff should be increased with a view to being able to undertake such work?—Yes, and the Standards Committee have expressed a rather strong opinion on that point.

141. (*Sir Courtenay Boyle.*) Which Standards Committee?—The Committee of 1870.

142. (*Sir John Wolfe Barry.*) In favour of it?—In favour of the increase of the staff.

143. (*Chairman.*) As to the determination of physical constants and numerical data, do you regard that as being within your province at the Standards Department?—No; I submit that it is our duty to avail ourselves of the best research on those points that we can with regard to physical constants and numerical data. The following (list handed in; *vide* Appendix), if I may be allowed to read them, touch us: First, the mass of the unit volume of air and of water; on those points, of course, we have much valuable information from the Royal Society and from the International Bureau at Paris and from the Reichsanstalt at Berlin. The next item is densities, co-efficients of expansion and elastic moduli of materials suitable for the construction of standards; that is an important point with us and one that we have had difficulty with. When we make a new standard as in the present case, where we have just had a new standard yard made at a cost of something like £500, we are anxious to determine its co-efficients of expansion and elasticity. But that is an operation which we cannot undertake; it is certainly a scientific operation, and we shall have to assume those co-efficients unless we can obtain assistance from Paris or elsewhere. Again, as to the materials for standard weights for primary purposes, as for assay purposes, we often wish to know apart from the specific gravity or density of the weight, of what it is really made. We have no means whatever of ascertaining that, and at the present moment we do not, apart from the specific gravity, know what the condition

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or alloy, as it were, of our standard weights may be. Numerical data as to the density and expansion of water are important for us, because they come in not only as to measures of capacity, but as to the connecting up of the measures of capacity with the measures of weight. Then, in regard to the investigation as to proposed new methods in metrology, we are now working on the methods laid down by the International Committee of Paris, but there has been in this country very little investigation as to the new methods of metrology, and there is no one certainly in the Standards Office who could carry out investigations like that. Then there are the chemical analyses of materials employed for standards purposes with a view to their exact reproduction whenever necessary; that is important in this respect that we do not know the exact constitution, if I may put it so, or chemical analysis of our primary standard pound weights. Although we might, perhaps, hit upon the same specific gravity that our present standards have, we could not reproduce them exactly unless we knew exactly what the chemical analysis of the original weight was. We have no means of determining that at present.

144. Have you ever considered what you would propose in order to remedy the deficiencies of which you speak?—I think it would be very desirable in such work to reproduce the means here afforded by the German Reichsanstalt as to the analysis of materials and the work of scientific research. (Statement handed in of scientific research, carried out at the Reichsanstalt, of importance to the Standards Department; *vide* Appendix.)

145. (*Mr. Rücker.*) Then you, as the head of the Standards Department, have felt the want of an auxiliary institution or of an increase of your staff to enable you to carry out scientific investigations directly bearing on your work?—Yes.

146. (*Mr. Chalmers.*) Has that been felt, should you say, for the purposes of ordinary commercial work—do you suppose that you are under any disability in carrying out your statutory duties?—Yes. Take the instance of the pound weight to which I have referred. We have no means of exactly reproducing it because we do not know its constituent parts. That involves some uncertainty as to any new weight that might be produced. That uncertainty would undoubtedly be felt in some commercial centres.

147. (*Mr. Roberts-Austen.*) I was going to ask just the same question in a somewhat different way. What is meant by the suitability of the material?—For instance, supposing you took the platinum-iridium alloy, do you mean that you would have no means of ascertaining whether the right amount of iridium was present?—Yes, and we should have no means of ascertaining whether other things were present besides the iridium, such as ruthenium and a small trace of iron, which is so important, as you know better than I do, in the alloy. We should have no means, and we have no means at the present moment, of finding that out for ourselves in our new standard yard.

148. And that is certainly unfortunate as regards your statutory powers?—Yes.

149. (*Mr. Chalmers.*) But taking that position, that would be a thing to do once for all, would it not? It would not be a thing which would be recurring every month, or even every year; it would be done once for all?—Quite so.

150. Have you ever thought of consulting the Government Chemist, for instance, on a point of that kind?—We have thought of it, and we have in other respects had much help from the Government Chemist; but we should hesitate to approach him in a work like this, because we know that it means continuous systematic work for some months. It is not a small thing to be done in a week.

151. But when done it would be done once for all?—Yes.

152. (*Sir Courtenay Boyle.*) For that particular standard?—For that particular standard.

153. If you have got a good many standards it would have to be done a good many times?—Yes.

154. (*Mr. Roberts-Austen.*) My point would occur every time you made a new secondary standard of platinum-iridium?—Every time we make a new standard we should want the same analysis made.

155. (*Sir Courtenay Boyle.*) What standard, the primary standard or a secondary one?—The primary standard.

156. (*Chairman.*) Probably all Mr. Chalmers wants is to get some general idea of how often the kind of difficulty you are speaking of would be likely to arise, or does arise in practice?—Not often, in regard to us, either as to the standard measures or as to the thermometers.

157. Have you given any consideration to the general question before this Committee as to the advisability of the establishment of a National Physical Laboratory to which some of the questions which you have mentioned and others might be referred?—It is a question that has been under my consideration, without reference to the Committee, if I may be allowed to say so, because from time to time I have felt the want of being able to refer to such a Committee in matters of scientific investigation, and to that extent in matters of original research there is undoubtedly a want in this country of some laboratory to which everyone, not only the Standards Department, might have access. Beyond that I would submit that at present there is no urgent demand for a National Physical Laboratory for purely standardizing purposes, and that that work is very well met (by comparison with other Standards Offices abroad) by the existing accommodation in this country.

158. In speaking of standardizing work you referred to the standards in what I should call the special Board of Trade sense, and not to general questions of fixing important physical constants?—I refer only to those standards that are recognised by our laws as being deposited with the Board of Trade.

159. (*Sir Courtenay Boyle.*) As regards physical research the Legislature has not devolved any responsibility upon the Board of Trade, has it?—No, excepting that if the Board of Trade had thought fit to cause a new standard in relation to temperature, gravities, or electrical standards to be constructed, the Board of Trade would consider whether they should not obtain the best scientific assistance.

160. Certainly, but except as regards fixing new denominations of standards, or reconstituting the old existing standards when destroyed, the Board of Trade have no responsibility of physical research?—None.

161. And therefore no duty devolves upon them of determining physical constants?—No legal duty.

162. In other words, our duties have to do with trade and not with science, except so far as science is necessary for trade purposes?—We, if I may say so, have to verify under the Act of 1878 for the purposes of science, and to carry out any operations that may be required for those purposes in regard only to comparisons of the standards referred to in the Act.

163. As regards only those standards?—Yes.

164. But not generally?—No, not generally.

165. (*Mr. Chalmers.*) I should like to ask you a question with reference to the commercial aspect of the standardizing work which you do—using the word standard with reference to your statutory duties in the Board of Trade sense, do you find that there is very much work that would come to you supposing that you had greater facilities than you have at present? You have spoken about certain steam gauges, for instance; could you tell the Committee to what extent you think that work would come to you (supposing you had unlimited scope) from business coming to you from commercial concerns?—I think work would come to us in large quantities.

166. From what other points of view—steam gauges you mentioned?—I am judging from applications we have had to test these instruments. The list includes steam gauges, water meters, and standards of light—and with regard to those I should say that during the last three years we have had numerous applications.

167. (*Dr. Thorpe.*) For standards of light alone do you mean?—Yes. It is work that has been much taken up in Germany. I think that has rather stimulated manufacturers on this side to make similar applications for the verification of their instruments. Then we have applications for the verification of hydrometers, although, of course, such instruments would be better done at a chemical laboratory. I think those are all the applications that are likely, if I may so say, to pay their way and support themselves as a voluntary testing.

168. (*Mr. Roberts-Austen.*) Do you think such cases would support themselves?—They would.

169. (*Sir John Wolfe Barry.*) Do you issue certificates with the instruments, or stamp them after they have been verified?—Yes.

170. If they are not accurate do you issue a constant showing the inaccuracy or the necessary adjustments?—Yes.

171. That is all certified, therefore, by your Department of the Board of Trade?—Yes.

172. How do manufacturers get their work done if they want certain thermometers or gauges of different kinds certified?—They come to us, and we verify manufacturers' standards and gauges for their own use, they paying the fee legalised by the Treasury.

173. Do they apply directly to you?—Yes.

174. And you have the power of either granting the request or refusing it, I suppose?—Yes, subject to the decision of the Board of Trade.

175. And you think the demand for such examination of instruments is growing rather?—Undoubtedly.

176. Is it known among the manufacturers that your powers of standardizing are somewhat limited, not only physically, but that under the regulations your main work is with weights and measures?—Yes, that must be the general impression among manufacturers. Then probably the fees that we charge may be somewhat too high for many manufacturers, although we are only allowed to charge fees on five-sixths of our work; we are not allowed to charge fees on statutory work, or any work that is done under an Act. The fees on voluntary matters amount to about £600 a year, which we think is a large sum for such voluntary verification.

177. And that might deter manufacturers of articles which are not in themselves very expensive from having them standardized?—Yes.

178. Those fees, I suppose, are known?—Yes, they are approved by the Treasury, and a printed copy of the list of fees is always given to a manufacturer. Our fees, I may say, vary from £20 to 6d. If a very accurate determination of a standard is required, a matter involving three or four months' work, as for the Government of India or Australia, or one of our Colonies, we charge a £20 fee; but if a manufacturer wants a very accurate standard weight, we charge him from £2 10s. to £5, and we give with that a certificate of its accuracy or its inaccuracy. (List of fees handed in; *vide* Appendix.)

179. Do you happen to know how those charges compare with those of other countries for similar work?—I think they are higher.

180. They are higher than the charges in other countries?—Yes, they are.

181. Are they higher, do you think, than in Germany?—Yes, I think they are.

182. And also higher than in France?—I am not so sure as to France.

183. Are they considerably higher than the German fees?—It is difficult to compare verification work. If we compare a matter for which we charge a £20 fee with a similar matter in Germany, I think there would not be much difference really in the fee; they do in Germany. much verification work for ordinary purposes at a low rate—and very useful work it is.

184. Do you find that you have to refuse to execute work from manufacturers on account of want of space, or want of appliances, or want of staff?—Not on account of want of appliances, because, as I hope the Committee will say when they see those appliances, they are quite adequate, but the staff is too small to undertake such work, and we have to limit ourselves to work that is strictly under the Acts of Parliament.

185. You have to keep to a yearly Budget, as it were?—Yes.

186. With that restriction do you find you have to refuse to do work for manufacturers?—Yes.

187. Is that a frequent occurrence or very seldom?—I do not think it is more than a weekly occurrence, perhaps about one case a week comes in where there is a new kind of instrument sent in and we are asked to verify it, then we have to decline, because we have not the means to do so.

188. Would you verify instruments made by instrument makers—take for example a planimeter; if he sent it to be stamped as accurate would you undertake that?—Not as a planimeter.

189. That would not be part of the work of your Department?—No.

190. Is that because it is not in the Act of Parliament, or what is the difference between a planimeter and a thermometer in that respect?—We verify the thermometer in the case of the petroleum apparatus because it is a part of the apparatus, and I think we should decline to verify a planimeter because there is no dimension in it which is represented by any standard in our custody. If we were asked to give the area or linear dimension of a planimeter we should give it in the same way as we give dimensions of different parts of a photometer.

191. There would be no means, then, of getting an instrument stamped with authority as accurate for doing what it undertakes to do?—No, not in the case of an instrument like the planimeter.

192. I only took the planimeter as an illustration, but there are many other instruments?—Yes, there are thousands of others.

193. (*Mr. Roberts-Austen.*) Take the verification of instruments used for ascertaining the mechanical properties of metals, would there be much demand for the verification of such appliances if you could undertake it?—Yes.

194. The moduli of elasticity, for instance?—Quite so. There would be a considerable demand for that, and outside the demands of the Standards Office we have been frequently asked to undertake such work for manufacturers.

195. (*Dr. Thorpe.*) I gather from your statements that you regard the proper function of the Standards Department that it should be directly applicable to commercial purposes, and that you do not see that it has any necessary work to do in connection with scientific and experimental investigation either of the materials you yourself use or of the things which are auxiliary to your work, is that so?—That is so. We are not organised for the purposes of research, and there is no obligation under the Acts of Parliament for us to undertake physical investigations.

196. Would you regard it, if you had the means, as your proper duty to do these things? What limits you—want of space, want of funds, or what?—If we had a sufficient staff we could very well undertake that duty; but even then it is not a duty that we are directly instructed to do under any Act of Parliament.

197. Are you not; because many of these physical constants, for example, are actually necessary to the definition of the instrument you use, and you require the knowledge of them?—Yes.

198. You, yourself, for example, have mentioned that it was necessary for you to know the constants of a certain metallic alloy which you needed for the construction of a standard?—Yes.

199. But you are not able to determine that?—No. It is quite true that we are obliged to use certain data and numerical expressions in our work, and it is also true that much of those data may be wrong, and we may know it.

200. Know it to be wrong?—Yes; but there is no obligation under the Acts for us to initiate new data or new numerical expressions.

201. There may not be any obligation, but is it not part, may I venture to say, of your duty as Superintendent of the Standards to take care that so far as you can the numerical data that you make use of are in accordance with fact?—It is; and so far as I can I do so. May I be allowed to point out this, for instance, as to the uncertainty of the expansion of water? We know very well that the tables of expansion we use now are not true throughout, but it would be impossible for a small department to undertake such a thing as the investigation of the expansion of water, so we are obliged to-day to accept the best recognised data.

202. That means in effect that you have to go to similar organizations to your own on the Continent, who have these scientific investigating departments attached to them?—Yes, we go to Paris, to the International Bureau, for all matters relating to mercury and alcohol, and the moduli of expansion and elasticity.

203. (*Mr. Chalmers.*) And that is not directly comparable to you. You are rather a member of that as other parallel institutions to you are members?—Yes.

204. (*Dr. Thorpe.*) But it means in fact that you are content to take your data from somebody else, and that in Berlin and Paris, for example, there are organizations somewhat similar to your own which do supplement their ordinary work of comparison by the original investigation which is from time to time necessary in connection with these standards?—Yes.

205. (*Mr. Chalmers.*) But in Paris it is an international body and not a national one?—That is so, and it was appointed very much for the purpose of research and not only for standardizing.

206. As a central body set up for research on behalf of various nations?—Yes.

207. (*Sir Courtenay Boyle.*) Could you state what we are contributing to the International Office in Paris?—When we joined the Metric Convention in 1884 we paid in an entrance fee of £1,775. We subsequently paid towards the arrears of Turkey and Peru £200, and our annual contribution since 1884 has been about £200.

208. (*Chairman.*) I think you have explained to us that there are investigations which you are not able to undertake on the ground of the difficulty or expense or want of staff—investigations strictly germane to the work of your department, although not absolutely necessary to be carried out from day to day—which you would naturally undertake if you had the means, but which you are not able to undertake?—Yes, there are such investigations.

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209. Are you acquainted with the work done at the Kew Observatory?—Yes.

210. Do you consider that that supplements the work done by your own department in any degree?—It does in some degree, as in the verification of thermometers.

211. Do you work in any sense in co-operation with Kew?—We do not.

212. But you are generally acquainted with the work that they undertake?—Yes, I am quite acquainted with it.

213. Would it occur to you to refer any applicant to Kew who came to yourself to undertake work that you were not prepared to undertake?—I have done that. Some years ago, for instance, Dr. Cotton came to me from the India Store Department with reference to clinical thermometers, of which a large number now are verified at Kew, and asked me to undertake the verification of these clinical thermometers; but I told him I had no staff for the purpose, and he had better go to Kew Observatory. Since that such clinical thermometers have been sent to Kew.

214. (*Mr. Chalmers.*) That is like the case of the steam gauges to which you referred?—Yes.

215. Would you regard those two as important instances?—Yes.

216. I did not understand you to mention any other instrument as really important?—The really important measuring instruments with reference to which manufacturers have applied to the Board of Trade for assistance, which the Department has declined, are steam pressure gauges, water meters, instruments used in the standards of light.

217. (*Dr. Thorpe.*) And I think you added, latterly, hydrometers?—Yes, but I was in doubt as to hydrometers whether the applications put to us have been sufficiently numerous. I think they must have been more numerous at Kew Observatory or elsewhere, because we have so often declined to test them, especially hydrometers with foreign scales.

218. Would you undertake the verification of a Sykes' hydrometer?—We have done so; we verified the present standards for the Canadian Government.

219. But you must have applications, surely, from the trade for the verification of Sykes' hydrometer?—Yes we have, but not many. I think the work of standardising Sykes' hydrometer is really done through the Inland Revenue Authorities in a very good way, because manufacturers appear to be able, so far as Sykes' hydrometer goes, for Revenue purposes, to get standards indirectly standardised at Somerset House.

220. (*Sir John Wolfe Barry.*) Have they got the proper appliances at Somerset House?—I think so. The conditions involved in the verification of such a hydrometer as the Sykes' hydrometer are simply floating it in two liquids of known specific gravity.

221. You only had reference to that particular thing when speaking of the appliances at Somerset House?—Yes, that is all.

222. What would be your attitude with respect to the verification of a Sykes' hydrometer coming from a large spirit merchant for example; would you decline to take it or not?—We should decline to take it.

223. Why?—Because we have no means for undertaking such work for trade, but where a Government, as the Government of Canada, apply to us, there we make an exception, and we should undertake to verify the hydrometer in that case as a measure of gravity.

224. But inasmuch as it is a comparatively simple operation, and there would certainly be a commercial demand for it, if it was known that there was some Court of Reference, I do not quite see what the logic of the position is, and why you should decline to undertake it. It is not as if it involved any very long or tedious set of comparisons?—The verification of an ordinary hydrometer is not a long operation by any means, but if we undertake to verify one or two for certain manufacturers we must verify for all, and these instruments are used by thousands. I have no staff for such a purpose.

225. (*Mr. Chalmers.*) But you do believe that there would be a distinct demand for that individual instrument?—Yes, there would, but not to the extent of the demand for other instruments, like water meters.

226. And arising out of Sir John Wolfe Barry's question, do you think the public would like to have a stamp on it of a Government nature rather than the written certificate which I understand you do send? Suppose you had power to put a Government stamp on instruments of the nature just mentioned, is that what you would imagine the public would like?—Yes, it is so. It would be a guarantee of the accuracy of the instrument.

227. (*Sir John Wolfe Barry.*) Something like the Hall mark?—Yes.

228. (*Mr. Chalmers.*) That is not a Government stamp. I mean an official stamp of the nature of a Hall mark?—Yes, I think the public would appreciate that.

229. (*Sir John Wolfe Barry.*) May I ask whether you give gauges of any kind which would enable a man to know whether the cross-section of a circular inch is a true circular inch?—Yes.

230. Or whether a circular half-inch diameter is a true half-inch in diameter throughout the whole area?—We verify such gauges; for instance, lately we were asked to decide in a dispute between the War Office and the India Office as to the size of certain gun barrels and certain cartridges that were sent out. We found that the gauges were of similar form to those which you have described, and that the gauge of one of the Departments was some ten-thousandths of an inch too small.

231. I suppose that Department had been working to that gauge for some years?—Probably so.

232. Therefore, until you undertook that investigation, as it were by an accident, there was no authoritative measurement of a circular inch?—The Departments had not come to the Board of Trade before.

233. And the trade had not come?—We often verify for the trade.

234. But the trade had not come up to that time to have a gauge, had they?—Yes.

235. They had?—Yes, for some years past. All the principal gauges used at engineering centres are verified by us.

236. Are they stamped in any way?—They bear the stamp of the Board of Trade.

237. (*Dr. Thorpe.*) Will you hand in the exact number of those various things which you included in the list you gave us of the instruments for physical investigation, which you declined to test and verify?—I do not show that on the list, but I will cause it to be shown, if possible.

238. (*Chairman.*) Is there any other matter that you wish to represent to the Committee?—I think not.

MAJOR PHILIP CARDEW, R.E., called; and Examined.

Major P. Cardew, R.E.

239. (*Chairman.*) You are, I think, in charge of the Electrical Department of the Board of Trade?—Yes.

240. And have been since its establishment?—Yes.

241. Would you give the Committee a brief sketch of the work undertaken by that Department?—The work so far has been the establishment of the standards of current, electrical pressure, and resistance. We have now got all our standardising arrangements in working order, and have just started taking instruments from the public and from manufacturers to test.

242. Your laboratory is located at No. 8 Richmond Terrace?—Yes.

243. And you have there electrical plant suitable for the needs of the Department?—For what I specified—for measurements of the three electrical quantities of which we have the standards.

244. Do you consider the situation suitable?—Yes, I think so, for such a limited scope of work.

245. Is the staff with which you are provided adequate for the work that you contemplate undertaking?—I think we may have to add another observer probably. Of course, we are merely feeling our way, as it were, at present, and we cannot exactly foresee how many instruments will be sent in, and at what rate they will come in.

246. (*Sir Courtenay Boyle.*) If they come in in any great quantity you will not be able to do it yourself, or with your present electrical assistance, will you?—If they come in in any great quantity we shall have to go for further assistance.

247. (*Chairman.*) I think the Committee ought to have on their Minutes a little more of the origin of the laboratory in the Electrical Department of the Board of Trade and of the work undertaken there?—It originated, as you may remember, in a deputation, which came to the Board of Trade in June, 1889. There was a deputation then to the President of the Board of Trade, asking for the establishment of a standardizing laboratory for the purpose of maintaining standards of the electrical units of current, pressure, and resistance.

248. And the laboratory was instituted with a view to that special limited work?—Yes. We exactly carried out what that deputation asked us to do. I think they put

forward a well-prepared scheme and an estimate. We have carried that out, and, taking the whole of the money spent from that date to now, I find that we have spent very nearly exactly what was estimated.

249. What advice did you take at the time of the institution of the laboratory?—As soon as we had got the means of generating and dealing with electrical energy sufficiently advanced, we appointed a committee to deal with the question of the establishment of regular standards for the electrical quantities, and we asked the Royal Society and other scientific bodies to appoint representatives to sit on that Committee.

250. (*Sir Courtenay Boyle.*) But only standards for the three quantities?—Yes; we have never gone outside those three.

251. (*Chairman.*) You would not regard it, I understand, as falling within your department to undertake investigations by which the exactness of the present standards might be controlled or checked?—I think that having those three standards, comparisons between these standards themselves afford a very good check of their constancy.

252. Taking your stand upon investigations originally carried out elsewhere?—Certainly; taking it that the standards as verified with the assistance of that committee exactly represent what at the time they were verified were considered to be the true values of these units, I do not think that it is likely that our standards could any one of them vary without it being at once apparent through the continual system of checking which we carry out.

253. (*Sir Courtenay Boyle.*) Suppose there was variance, which would be the standard?—I think that it would be desirable then again to appeal to the recognised scientific bodies of the country.

254. Just tell the Committee where the ohm is deposited at present?—It is in one of the rooms of the laboratory at 8, Richmond Terrace.

255. Is that the only exemplar that exists?—There is one standard pattern of an ohm which has been verified, and is now marked as the standard. But, of course, we have a great many copies of it, which can be easily compared, as you are well aware, with the standard itself. We also have had many copies made in this country, and we have also copies made in Germany, and verified there.

256. I have not made my question quite clear. There must be more than one standard of each denomination, otherwise if the standard goes wrong there is no means of putting it right; surely there is more than one standard ohm?—No, there is only one absolute coil of wire marked at the present moment as the standard; but we have many copies of it, you may say, of the same pattern, any of which could serve the purpose.

257. Does the Order in Council fixing the new denomination rely upon one exemplar only as the standard?—Yes.

258. (*Chairman.*) Would you contemplate the possibility of that standard being at some time dethroned in case of discrepancy?—We can certainly contemplate the possibility of it, because, of course, we know that everything is liable to change; but we take every precaution that we can. The instrument is kept in a room, of which the temperature is maintained night and day within very close limits. I think certainly if a standard coil of the form that has been usual is exposed to great changes of temperature, it is extremely likely that there would be variation produced in its resistance on account of the stresses to which it would be subjected; but if you take a standard coil and keep it always at a very uniform temperature it is extremely unlikely that it would change.

259. (*Sir Courtenay Boyle.*) There is no standard column of mercury there?—No, we have no column of mercury there.

There is no standard column of mercury in existence?—I have never seen one. I have never seen anything which exactly complied with the definition of the ohm in the terms of a column of mercury.

260. (*Chairman.*) At any rate there is none at the Board of Trade?—No. That was because acting upon the advice of the Standardizing Committee we preferred to take the wire standard. As you are aware, we had several distinguished scientific men from Germany, who worked with us for some time, and thoroughly satisfied themselves that their standard of resistance was the same as ours.

261. (*Sir Courtenay Boyle.*) Have they got a column of mercury in Germany?—At that time they had not—they were not using one.

262. Do they compare with a coil of wire?—They were comparing with coils of wire; they brought their coils of wire here.

263. (*Chairman.*) I think it is probable they would not carry the mercury standard about; but they might have one in reserve?—They could not carry it about with them. I am not quite certain, but I rather think that if there is one it is not in use; that is what I rather gathered from Doctors Kahle and Lindeck.

264. (*Sir Courtenay Boyle.*) If you set up a new coil you would have to constitute that new coil in terms of a column of mercury, or by comparison with a column of mercury, otherwise you would not get the true ohm, would you?—No. If you remember, in the report of the Standardizing Committee we gave the value of the old British Association's standard in terms of our new standard, and really our standard you may say is based upon the British Association's standard, which has been kept for many years with great care, and we had the benefit of all those years' experience.

265. (*Chairman.*) Do you verify resistances sent to you by the public?—Yes.

266. Would you undertake that task in the case of very small resistances, for instance, the 200th part of an ohm?—Yes.

267. Could you tell us at all how that comparison is effected?—It would be effected on the principle of passing a large current, and measuring the fall of potential in the case of these very small resistances. As a rule these very small resistances are intended for the passage of a large current.

268. What would be your standard of reference in that case?—We should give the resistance by measurement of current and electromotive force in such a case. Of course, it can be done in another way—it can be done by working down by the sub-multiples from the ohm, but as a rule this way is more satisfactory to manufacturers, because these instruments are intended to be used with large currents, and they want us to determine the resistance with a certain current passing through—that is to say what they want is the fall of potential.

269. I understand that you regard your work as strictly limited to the duties prescribed by the Acts of Parliament, and that you would not regard it as within your province to undertake anything in the nature of auxiliary investigations into electrical matters?—Certainly. I should say it was outside our province as at present laid down for us.

270. You would fully recognise, I presume, that there are plenty of such questions constantly arising which require solution, and of which you need to know the solution?—Yes, it is important to the whole scientific, and, you may say, the whole commercial body, of course to know the solution of fresh scientific questions.

271. Have you any view to lay before the Committee as to the question referred to them of the establishment of a general national physical laboratory, whether as an extension of Kew or in some other form? Have you considered at all the question of the advisability of such an establishment?—I think, speaking outside any official capacity, that it certainly would be to the credit of this country to take the lead a little more in scientific matters, as I am sure we ought to be able to do, and no doubt we should be helped in this greatly if there were a laboratory in which every kind of physical research could be carried out with the best instruments and appliances. Of course, how far that should be entirely maintained by the State is a very big question. In Germany, I believe, it was a happy union of private liberality, and of the State coming to its assistance that got their Reichsanstalt.

272. If such an institution were established have you any view to put before the Committee as to what relations, if any, should exist between it and the departments of the Board of Trade?—It does not seem to me that any good thing would be secured by upsetting the arrangements we have made for maintaining the electrical standards and for comparing instruments with them.

273. Do you think that the limited questions at present dealt with by the department of the Board of Trade are satisfactorily dealt with?—If I may say so, without appearing to cry up our own place, I think it is so. I think, for instance, that we can maintain a constancy of current and electromotive force such as I do not think can be exceeded in any other institution. I have not seen the Reichsanstalt, but I know that the German scientific men to whom I have referred were pleased even then with what we could do, and, of course, we have improved since. This having been thoroughly completed, it would seem a great pity now to wipe the whole thing off, and start again. We were asked to establish a certain thing, and we have done it exactly on the lines which were laid down for us.

274. Supposing such an institution was established at

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some distance from London, would it be capable of doing with equal convenience the work that you do at the Board of Trade actually in London?—I think not. I think the manufacturers would prefer coming to us.

275. For ordinary every-day purposes?—Yes, for standard ohms and instruments. I think they would find it very convenient.

276. On account of the more convenient situation?—Yes, and also because here is an institution in which they know there is certain work, and nothing else, to be done. If they take their things to a big physical laboratory, unless there is a tremendous big staff and very good control, and everything is well looked after, they have a suspicion that their instruments are put on one side because there is some great research going on which takes the whole power of the place.

277. (*Mr. Rücker.*) Does that hold with regard to a place like Kew, do you think?—Kew is a limited place, very much as we are.

278. Would it hold with an enlarged Kew?—It depends upon what is carried out in the enlarged Kew. Kew at present does not undertake research.

279. A certain amount of research is done there?—Well, yes.

280. (*Dr. Thorpe.*) But surely a manufacturer who takes a barometer there knows that he is not thrust out of the way because there are clinical thermometers to be compared?—No, possibly not, but a manufacturer might bring a standard ohm to a big place, and it might be a very long time before he got it back again, and that might be possibly because this big place was undertaking all kinds of elaborate physical investigations as to what an ohm was, and whether they had got an ohm. That is a sort of thing which manufacturers do not appreciate.

Friday, 5th November 1897.

PRESENT:

Mr. A. W. RÜCKER, D.SC., F.R.S. (in the Chair.)

Mr. W. C. ROBERTS-AUSTEN, C.B., F.R.S.
Mr. ROBERT CHALMERS.
Dr. T. E. THORPE, F.R.S.

Mr. L. BLAIKIE, *Secretary.*

Major PHILIP CARDEW, R.E., recalled; and further Examined.

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281. (*Mr. Rücker.*) Having seen the Laboratory, there are one or two questions we wish to ask you further about it. In the first place I understand you to say that if a large number of instruments were sent in for testing you would want additional assistance?—Yes, certainly. Of course I do not want to make too much of it, but it is very difficult to carry on the work with the assistance we have got, because my duties take me away so much.

282. If the number of instruments increased very largely you might require a considerable addition to your staff?—We should certainly want one or two more observers.

283. Does that hold good with regard to space also; would you want more room?—I think we could have a very considerable number of instruments. In the arrangements we have made we have especially considered the question of dealing with fairly large quantities of instruments, but have assumed that there would not be a large number of different types of instrument. If it came about that the manufacturers, instead of attempting to calibrate their own instruments, found it more convenient to send instruments by the dozen, or even by the hundred, to us, or to what we became, and we had to give them the readings for certain specified fees, I am inclined to think that they would find it pay them very well to do that.

284. The point I am asking you about is, if all that occurred, would your present space be sufficient, or do you think you would require any considerable enlargement of space?—I think with our present space we could deal with that. Take the ampère meters; I think we could deal with them at the rate of twenty at a time. Suppose we have twenty ampère meters all reading up to 100 ampères maximum, which is a very common type, they would not take very much space, assuming that they did not require to be put very far apart. Of course some very exact instruments might require to be put several yards apart and to be isolated, and so on; in that case we should have to do them in smaller numbers. But take the ordinary commercial instruments which we know are going to be put on the switch-board close together—a position in which they may influence each other a little—we should not take any grand precautions in such a case; we should simply connect the whole thing in series, put it into our main as I showed you, and take the necessary readings, taking care to keep our current perfectly constant, while one or two readers jotted down the results. In that way we could deal with a large quantity of instruments.

285. With regard to the instruments, do you think it is likely that in the future you will have to add to the standards you are at present using?—Of course, what we have been considering is capacity.

286. That is a possible addition?—When you come to that kind of standard it will want a great deal of consideration, I think, before we undertake to deal with them. Take capacity, for instance; it is not by any means quite established how capacity should be measured to give a standard value. In the same way, say, with self-induction, you can by different means of measurement get different values.

287. Excuse me, but I am assuming that the thing could be done satisfactorily?—Supposing it could be done satisfactorily and that there was a general agreement how it was to be done, for instance, that capacity should be measured by the current passing——

288. We need not go into details; we only want to deal with the more general questions. Would you be prepared to undertake that?—As at present advised, I think not.

289. You think not?—No; unless it can be shown that questions of capacity directly come into questions of buying and selling, that is to say, as measures. At present a manufacturer has to provide a cable, say, which is specified to be of a certain capacity, and to that extent you may say that capacity is of commercial importance; indeed, it is of very great commercial importance, but it is not a quantity which is bought or sold as a quantity—I think it is rather apart from such things as quantity and energy supplied.

290. Coming back to the laboratory which we saw the other day, do you think that, supposing an electrical railway came near you, that would seriously interfere with the efficiency of the laboratory?—No; I do not. As regards vibration, we rather court a little vibration for our instruments, and as regards magnetic disturbance our instruments are all so arranged that they are either totally insensible to it, or we, by reversing our currents, cut out any disturbance.

291. But the reversal process would not hold good if the disturbances were rapidly changing, would it?—I should not like to see an electric railway driven up Whitehall.

292. That would be a great disadvantage?—I think that an electric railway as near as that would be.

293. I was meaning one like that?—It would be.

294. (*Mr. Chalmers.*) Are you threatened with such a railway?—No, I am not sure that we are; this is the first I have heard of it.

295. (*Mr. Rücker.*) I may say that these difficulties have occurred in so many places that it really is a very serious question in regard to any laboratory in a town now, whether or no an electric railway would or would not interfere with it. I suppose you can say that if an electric railway came up Whitehall it would be a disadvantage?—Yes; it would be.

296. Do you take up the position at the Board of Trade laboratory that you are to anticipate demand, or to follow demand; in the establishment of any new unit would you wait until there was a popular demand for it, or would you prepare for it?—I think we should wait

until we had been approached. We waited in this case until we got a distinct representation of the opinion of the trade that it was wanted.

297. The question has been raised as to the permanency of the Board of Trade standards; are you aware of that?—Do you mean about the resistances?

298. Yes; having regard to the fact that that question has been raised, do you think it desirable that you should be supported by an advisory or controlling body of scientific men on whose authority an answer should be given to any such questions?—I certainly personally would hail assistance from an advisory body.

299. You would?—Oh, yes; but at the same time I am prepared to defend the constancy of our standards.

300. (*Mr. Chalmers.*) As regards the existing demands upon you, I understand that you are satisfied with your buildings?—Yes.

301. And that you are satisfied with your appliances?—Yes.

302. And so far as existing demands are concerned, would you say that you are also satisfied with your staff?—No; I do not say I am satisfied with my staff, as regards number.

303. Your duties, roughly speaking, are to carry out a statute?—Yes.

304. And in your opinion you are, except for the staff question, perhaps, in a position to carry out your statutory duties?—Yes.

305. Your work, I think you told us when we were looking at the laboratory, tends to increase as regards private people coming to you?—The official routine has only just commenced. We had taken instruments unofficially and without charging anything, in order to perform such public service as we could before we were prepared to take fees; but we have only just commenced the routine of taking fees and doing instruments officially.

306. The work you have undertaken on these private lines for manufacturers you have undertaken at the request, as it were, of the trade?—Certainly.

307. The trade feeling that there was a necessity for something of a Government nature?—Yes, to give confidence that the work would be of a standard nature.

308. It having been found by the trade that any existing institutions which there may be scarcely met their purposes in their entirety?—I think that is so. At the time the deputation asked us to undertake this work there were very few places where people could go to get anything like a standard measurement.

309. May I ask what the deputation was; was it a deputation of manufacturers—I am quite ignorant about it?—There were representatives from the various scientific societies and manufacturers as well. It was a thoroughly representative deputation, and both Lord Kelvin and Lord Rayleigh spoke.

310. I suppose as regards the advisory body it would be a question, would it not, of the interpretation of statutes whether they could come in under the conditions under which you at present work; they could not have any formal status at present, could they?—No.

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311. The Board of Trade does the work, and you act for the Board of Trade?—Yes. They could only come in to this extent, that they might advise either me or the Board of Trade that in their opinion a certain standard should be disestablished and measures taken to correct its value, or something like that. We have the power under the Weights and Measures Act not only to make standards, but to unmake them as it were, and to remake them.

312. But all that would be of an informal nature under present conditions?—I should think it might be done much as the Advisory Committee for the Greenwich Observatory do their work.

313. (*Mr. Rücker.*) That is in part a governing body?—Perhaps I am not sufficiently familiar with the constitution of that body. I may say on the general question that I do not at all want to keep our standards to ourselves, as it were. We hail any advice from scientific people, and are only too glad if people will take an interest in our work and come and see what we are doing.

314. (*Mr. Roberts-Austen.*) With regard to that advisory body, if questions arose as to the constancy of the standards of resistance as affected by molecular change in the alloys used, to whom would such questions be referred at present. Would you go to the Royal Society or where?—I think we should probably apply to the Royal Society to assist us with advice on the subject. The Royal Society is accustomed to bear such burdens.

315. Would you not go to the Standards Department next door?—No; the Standards Department could not undertake an investigation into the possible changes of alloys.

316. (*Mr. Chalmers.*) There is of course the possibility of the Government chemist being appealed to. Would you go to the Government chemist?—Yes, in the case of any distinctly chemical investigation, of course we should go to the Government chemist, but I think as regards the standard of resistance you must differentiate between adopting one coil of wire and sticking to that for ever without the possibility of changing and saying, "Well, if that thing changes our unit must change with it," and throwing overboard all other coils of wire. We have got a large number of coils of wire, and those coils of wire have been kept with considerable care for a great many years, and the whole civilised world knows the value of the standard of resistance within a very small percentage. I am not, myself, very seriously afraid of our standard of resistance varying without our finding it out.

317. No practical difficulty has arisen as yet?—No. You see the manufacturers of standard instruments are themselves scientific people, so that they know what they are doing.

Mr. Francis Galton, D.C.L., Hon. Sc.D., F.R.S., called; and Examined.

Mr. F. Galton, D.C.L., &c.

318. (*Mr. Rücker.*) You have been a member of the Kew Committee for many years?—Yes; I have.

319. And chairman for eight years?—Yes.

320. You are familiarly acquainted therefore with the constitution and the work of the Observatory?—I am.

321. I believe that a history of the Observatory has recently been published?—Yes.

322. Would you be willing that that should be handed in to this committee?—Certainly.

323. That being so I think we need only ask you two or three questions on that point. Perhaps you will tell us in very short outline the history of the Observatory?—Allow me to skip over the earlier portion of the history. It first belonged to the Crown. It was built for George III., and was in more or less use for many years; then I believe it was in next to no use at all. At that time many members of the British Association were anxious on many grounds to have a physical observatory of their own. The grounds are stated in a letter written by Professor Wheatstone, of which I have a copy. It was to be a place where experiments might be carried on, where certain instruments might be standardised, and where—I think it was as early as that—some instruction might be given as to how to use them. It continued under the charge of the British Association for many years, but was a very heavy weight upon its funds. At last it cost them as much as £500 per year, and there was a revolt amongst many of its members at so much of their narrow income being devoted to this subject. Then there was a consultation between the Kew Committee and the Council of the Royal Society, the details of which I cannot tell you, but it ended in the Council of the Royal Society taking it, and in Mr. Gassiot, the then chairman, handing over at once £10,000 towards its maintenance. It paid its way thenceforward, but it went on in a comparatively narrow scope until latterly, when the amount of work began to increase, and consequently that of the fees received, by which new instruments could be purchased and new experiments might be made for fresh standardising, for each fresh standardising undertaking requires a great deal of costly previous work. Thus it went on and on, and in the last eight years it has come to this stage, that it is self-supporting in respect to everything except research, that is to say, all the standardising pays for itself, and we have the interest of Mr. Gassiot's fund, between £400 and £500 a year free that we utilise for enlarging our scope, which we have done year by year, or for structural alterations.

324. The researches that you speak of are chiefly researches carried out with the view to improving the standardising work at the Observatory, are they not?—Chiefly, not wholly.

325. The Kew Observatory is indebted to the Government for the site and the building, I think?—It is.

326. It is on Government ground?—Yes, with a very small rent, £25 I think a year, or perhaps a little more for the extra land lately given.

327. (*Mr. Chalmers.*) Do you pay rent?—Yes, to the Government, through the Woods and Forests Department.

328. (*Mr. Rücker.*) Beyond that the Kew Observatory is not indebted to the Government in any way?—No, except that they pay for the repairing.

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329. (*Mr. Chalmers.*) Which costs about £150 a year?—It may, but I do not know.

330. (*Mr. Rücker.*) Then, coming to greater detail with regard to the present work of the Observatory, would you tell us precisely how the Observatory is governed?—The supreme government is in a Committee nominated by the Royal Society, and the executive part is governed by a Superintendent appointed by that Committee. The Committee itself meets once a month except in the Recess—altogether, perhaps, ten times a year—and there are more or less formal Sub-Committee meetings to determine special points. For example, there was a Photographic Sub-Committee, as we desired to test photographic lenses. There are very few people existing in England who have the theoretical and practical knowledge required for such a purpose; foremost among these is Captain Abney, who is a member of the Committee and greatly helped us, but he is a very busy man; also Major Darwin, of the Royal Engineers, lately a Member of Parliament, who had been the head of the Photographic School at Chatham, and who, though not a member of the Committee, gave a very great deal of help, and spent days and days over the subject. Then, again, there is the Thermometric Sub-Committee, which you know better than I do, consisting of three or four members who are experts in the higher thermometry; they meet and advise the Superintendent when difficulties occur, which are often numerous. In working with new apparatus, nothing goes quite smoothly; experience shows that matters of principle even, and many matters of detail, are continually cropping up, which are rather beyond the power of any one man holding the office of Superintendent to deal with by himself, however able he may be, and Dr. Chree is an extremely able manager.

331. Do you find in the standardising work that it is desirable to be continually in contact with scientific experts and to take their advice?—Certainly. It might be done in two ways—there might be a little less outside and more inside help than at present. The waste is that the Superintendent has to summon together gentlemen who are extremely busy, to arrange for their meeting if he can, or to correspond with them; but, if there were two or three men nearly as capable as himself at the Observatory to advise with, he might settle much of this off-hand. It wants many skilled minds to do it well.

332. That means that you think the staff requires strengthening?—It requires strengthening on the scientific side by the addition of a few highly educated men.

333. And in your view there would be an economy of labour if more of the work were done inside?—There would then be a great economy of labour, and I should think the work would be better done, because in so many cases you want to have the things before you, and to be familiar with the actual working—these people on the spot would be in that position—otherwise a quantity of material information has to be brought to London, and it is not supplied in the same fresh form.

334. You would not propose to substitute an internal Government—if I may use the phrase—for the general control by the expert committee; but you would still have a governing body somewhat similar to the present?—I think it would be better if it were similar to the present.

335. (*Mr. Chalmers.*) That depends to a great extent on the variety of the subjects which come up?—Yes.

336. Specialisation is so great that you could not expect, could you, to have a staff inside which could cope with all the specialist questions which arise?—Yes, I think we could.

337. You could, of course, theoretically if you put the whole scientific world in, but for practical purposes, could you?—I should think between four and six would do it; I have taken some opinion about it. Of course, we do not care about taking in hand the things that are of very small importance.

338. I want to see the amount of specialisation which you have in your committee; how many sub-committees have you?—At present that part of our work is often done informally; very often one asks a particular person to go into a particular topic, or one of the members undertakes to do so.

339. (*Mr. Rücker.*) I believe these special committees have often been appointed when new work is undertaken, and therefore they only last for a time; but at the present moment, so far as I know, there are only two important committees sitting?—There are, I think, four just now. In addition to the two I have mentioned, there is the Magnetic Committee for the testing of ships' compasses, and then I really do not know whether the Cloud Committee, which General Strachey managed, for inquiring into the height of clouds, is or is not going on; I do not think they have exhausted the matter yet.

340. To be quite clear, your idea is that there should be a superintending expert committee having under them a larger body of experts that at present exist at Kew?—There is only one that I should call a high-class expert at Kew at present.

341. And you want more?—Yes.

342. If the work of the Observatory were, for any reason, greatly enlarged, do you think any changes in its constitution are desirable other than those we have referred to?—I do indeed. I do not think we are half enough in touch with the scientific world, or sufficiently largely in touch with the manufacturing world—always supposing our scope were enlarged. So far as I can see that is only to be done by a large committee like the General Committee of the British Association, who appoint a Council who are the *de facto* managers.

343. Then you would have the management divided into three grades—first, a large committee which meets at long intervals?—Yes, which should be supreme, and which should meet at long intervals, say annually; then a council elected by them who should meet once a month.

344. And then, of course, the Superintendent?—Yes, under them.

345. Next as to the work of the Observatory, we shall have the advantage of hearing Dr. Chree; but I think we should like to hear a little from you on that point also. The Observatory standardises many instruments for trade purposes, does it not?—Yes.

346. What are the principal instruments?—They are very numerous. First of all there are all the thermometers, and there are all the meteorological instruments; then there are, for the navy, sextants, telescopes, and opera glasses; then there are a number of magnetic instruments for use abroad; also lenses for photography, and what you might call marine thermometers—deep-sea thermometers.

347. I do not want you to give me an exhaustive list?—Very good. I have left out chronometers and high-class watches in the list I have given.

348. The great bulk of the instruments so standardised at the Observatory are standardised for traders?—Yes.

349. They are sent in by dealers in the instruments?—Yes, and by the Government also.

350. A comparatively small proportion are intended for scientific research as apart from instruments to be sold? Or, to put my question in another way, comparatively few are sent in for individual scientific men?—That is so. The magnetic instruments are mostly sent in by foreign observatories; we standardise them, but they are not very numerous.

351. To take one particular case—the watches—were you asked by the clock and watchmakers to undertake this work?—Not at all; I rather think it was my own suggestion in the first instance.

352. You thought it was desirable?—Yes.

353. Have the trade, nevertheless, found it useful?—Very much so, indeed. They are increasing every year in numbers, and the improvement in watches is very great. At first, many watches priced at upwards of £100 would not get a first-class certificate.

354. Then the issue of certificates has actually improved the standard?—Yes.

355. Do the leading watchmakers send in their watches for trial every year?—They do.

356. There is, I believe, a competition, and marks are assigned?—Yes, and those who gain marks up to a very high standard have their names printed in the report.

357. I believe I am right in saying that the number of those who get a high standard has lately so increased that it has been necessary to reduce the number of those whose names are actually published in the report?—Quite so.

358. Then in that instance the work of the Observatory went before the demand of the trade?—Yes.

359. And, nevertheless, the trade has found it useful?—Quite so.

360. Are there other instances of that sort?—I should say that in the case of clinical and other ordinary thermometers it was almost forced upon them.

361. (*Mr. Chalmers.*) Forced upon the Committee or forced upon the trade?—Upon the trade. A few scientific people found their thermometers so bad that this was undertaken, and now it is a very large branch of the work.

362. When you are satisfied with a watch or with a thermometer do you put on a mark or do you give a certificate?—We do both; we put on a mark and give a certifi-

cate, and on that certificate we mention its performance; if it is a thermometer, for instance, we mention its errors at particular degrees, but the errors being within the allowed limit it gets its certificate.

363. Do you find that your mark has the value that on silver applies to a Hall mark?—Quite.

364. They are satisfied with that?—They are very well satisfied.

365. (*Mr. Rücker.*) To summarise what you recently stated you think it is for the public benefit, and for the good of the trade that a standardising institution should sometimes go ahead of the demand instead of following it?—I am perfectly sure of it.

366. With regard to the other instruments you have a very large number of barometers for instance, have you not?—A very large number for the mercantile marine and the Royal Navy.

367. And sextants, which are also, of course, used at sea in large numbers?—Yes. That was entirely, I may say by the way, a suggestion of my own. I was busy in the Geographical Society in those days, and I urged that our instruments should be examined; well, they were, and now sextants are largely sent by the Admiralty also. They were often bad at first—the glasses were bad, the graduation was bad, the telescopes were bad, but now they are all improved.

368. In the case of compasses, the Admiralty, I believe, examines the compasses for the Navy?—Yes, for the Navy, but not for the mercantile marine. One gentleman, a shipowner or an insurer, I cannot quite say now, wrote to us that he would be glad for the safety of the ships if the mercantile marine compasses could be examined and standardised in the same way that the Royal Naval ones are, or nearly in the same way.

369. And the Committee has taken up that work?—Yes; they took a great deal of trouble owing to the want of having experts at hand.

370. It has only just been started?—Yes.

371. So that you can hardly say how far it has been successful yet?—No.

372. That also is an instance in which the Committee has gone ahead of any general demand made upon it?—Quite so.

373. With regard to the Meteorological Council would you kindly tell us the exact relations of the Kew Committee to the Meteorological Council?—The Meteorological Council give it two grants, or rather one grant divided in two ways; one is to maintain an ordinary first-class self-recording observatory—that is the principal one. The Meteorological Council pays it as it pays other self-recording observatories—£250 a year, I think. The remaining portion of the total grant of £400 a year is for the purpose of having experts always at call, to do anything that they want done, as to go down and inspect instruments, and they are used very much.

374. Then are you the inspecting body for the Meteorological Council?—The Kew Committee is not wholly so. The Meteorological Council fixes its own inspectors, but there is always a risk of something going wrong, and something constantly does go wrong, and then Kew is applied to to put it right.

375. If any of the instruments are out of order Kew is called upon?—Yes, as a general rule.

376. So that it serves as a scientific advisory body to the Meteorological Council in that respect?—Quite so. Let me add that the two bodies overlap very much; I am one of the oldest members of both; in fact, I am the oldest member of both.

377. Are you satisfied with the site of the Observatory?—Yes, there are many good reasons for it. Of course, there is the isolation, and then the distance from town is not a disadvantage I am sure to the tradesmen.

378. (*Mr. Chalmers.*) There is plenty of room at Kew, or there could be room?—There is plenty of ground room, but not enough for many new detached buildings or for much extension of the existing buildings. I think if the work was extended it would be advisable to have a little more ground. We have five acres, but you do not know what may come up to the existing enclosure. Golf is played outside, and golf balls come over the enclosure where there are glass instruments exposed. It would be safe to have a little more room if the buildings were to be largely extended, but the ground is quite enough for us now.

379. (*Mr. Rücker.*) Is the distance from the railways satisfactory?—It is a great advantage.

380. The site is damp, I think?—The site is damp; but that does not make any of the houses damp; neither the main building nor the detached ones.

381. That fact does not interfere with the work of the Observatory?—No.

382. If the Observatory had larger resources at its disposal, are there any other branches of work which you think would be useful to science or trade which it would take up?—I am sure there are many. I have rather discouraged extensions, our hands being overfull; but I think that whenever a thing is bought and sold on a large scale, that thing, as a rule, should be standardised. I should be very glad if whatever I bought had a certificate from an independent person that it was good.

383. You think there is scope for a considerable increase in that kind of work?—Very considerable.

384. (*Mr. Chalmers.*) That would be so, as you say, in matters of considerable importance in trade. There are a great many watches, and a great many thermometers, for instance, bought; but not perhaps in the case of instruments of which only one or two are made in the course of a year, or probably in a decade?—I will not say that. There was an instrument which I was much interested in a long time ago; it was, in fact, the parent of the present heliostats. I went to the best maker to have it made, but the errors in it were continual and very great. They did not furnish me with plane parallel glass, and that threw everything out. I should like to have ordered those instruments subject to verification.

385. It would cost a great deal of money to standardise an instrument which is very rarely made, would it not?—No.

386. Surely?—No. If it is a question whether glass is sufficiently plane and parallel, it is answered by merely reflecting the sun against a wall some distance off, and seeing that it gives a round disc.

387. I was not taking that individual case, I was speaking generally of the case of an instrument which was very rarely made. I understood you to say earlier in your evidence that before you could do any standardising work there must be a lot of preparatory work?—Yes, for a new class of instrument.

388. And if that new class is very small it would entail expense which would be, I think I understood you to say, outside the scope of anything you have hitherto done; but am I to understand that it is outside the scope of anything that you propose to do as a practical question?—I was rather confining my illustration of the plane and parallel glass to one species of a genus with which the Observatory has been already engaged; there are many species in a genus, and in each class you can have many varieties. A new class sometimes requires a good deal of preparatory work.

389. (*Dr. Thorpe.*) That of course would depend on the particular class?—Of course.

390. For instance, supposing that you are called upon to test the planeness of a piece of glass, that is an operation that does not require very much preparatory work, and yet it might be a very important operation?—Yes.

391. And there might be a number of instruments in which that operation would be essential?—Quite so.

392. (*Mr. Chalmers.*) You lay stress on the fact that it is a thing in considerable demand, I think—as you said—a thing that is bought and sold in considerable quantities?—It is requisite in proportion to the demand.

393. As regards the case of the thermometers you said that the testing of them was forced "on them," and you then said that "them" in that case meant the people who made the thermometers?—Yes.

394. Was it forced on them by the scientific people who wanted to buy the thermometers?—By certain scientific people.

395. It was not so much that you started a standard of thermometers as that the scientific buyer wished to buy an article which would be of greater value and declined to buy the cheaper one, and therefore the manufacturer had to supply an article of the kind that was demanded by the buyer?—It centred in that.

396. (*Dr. Thorpe.*) I should rather, I think, put it this way: It was the existence of a court of appeal to which the scientific buyer could go that rather forced the hands of the trade. Was it not so?—Thermometer testing began a little before I was connected with the Kew Observatory, but I know at first there were numerous objections made by different people of a conservative character about what they thought an unnecessary trouble.

397. Are you speaking of makers and manufacturers?—Yes; and of other people too. But the testing was persevered in, with the result that for many successive years at exhibitions a diagram was exhibited made by the then superintendents of the average proportion of thermometers that failed in each successive year, and the improvement was most marked. The numbers of failures to obtain a certificate were very great at first, but the instruments gradually became better. Very often tradesmen and manufacturers go down to Kew and declare that their

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instrument is good although Kew has said it is bad; and in every case, I think without exception, they have gone away convinced that it is bad.

398. (*Mr. Rücker.*) It has had an educating effect on the manufacturer in that way then?—A very great effect.

399. (*Mr. Chalmers.*) Have you thought of any individual branch of work which you could take up, and which you might say there is a demand for you to take up, beyond thermometers, watches, and so forth?—I have thought vaguely upon it, but I would rather not commit myself to any expression of opinion, for it is not an easy matter.

400. There is nothing of a very crying demand that occurs to you at the moment?—In my particular line, the part I know most about, I do not think there is. I know nothing properly of the electrical part, but I fancy there is a good deal to do with resistances, and I know nothing about chemistry, and nothing about the purity of the things that are supplied.

401. (*Mr. Roberts-Austen.*) Do you know anything about the modern applications of the microscope to the structure of metals and alloys; is that a problem which has occupied your attention at all?—It has not, I am sorry to say. I know that that is a very important thing, and I should think possibly that strains in a transparent body might be investigated by the polariscope, but all that I do not understand.

402. And even strains and stresses in opaque materials?—Possibly.

403. (*Dr. Thorpe.*) Photographic lenses are examined at Kew, are they not?—We are beginning; it has not taken on as yet. Perhaps our examination, which was very thorough, gives results that the buyers are not sufficiently educated to understand, and the intention is to change the examination so as to make it cheaper, and of a more understandable kind. At present the lens is examined in something like sixteen different ways, without a single photograph being taken, and it is a very beautiful process; it is chiefly Major Darwin's. The plan that will be adopted probably will be to give two photographs in which there are various test lines for definition, for want of rectilinear—I do not know the phrase to use—and rectilinearity is too long a word, but you know what I mean—and much else. The correction for colour is given perfectly without the photograph. You notice the focus when the image is in the red light, and again when it is in the blue light, and if there is a shifting of the focus you know it is not correct.

404. If you were to extend that class of work, do you think there would be a popular demand for the examination, we will say, of ordinary spectacles by a standardising department?—I could fancy that; I do not know the secrets of the trade, but I should fancy that if astigmatic spectacles were ordered of a certain quality it would be a very proper thing to test them to see whether the man had made the axes of the two curvatures in the proper directions, and the concavities and convexities of the proper amount.

405. At present, of course, the purchaser of these spectacles relies solely upon the trader?—Quite so.

406. And he has no appeal?—There is no appeal, and he cannot himself test the spectacles.

407. Therefore it might be generally a useful thing that he should have the opportunity of an independent and perfectly unbiassed court of appeal?—Quite so. If it were an operation that would cost only about 1s., then it would be worth while to add 1s. or so extra to the price of something that cost nearly £1 in order to test it.

408. (*Mr. Chalmers.*) Has there been any demand for that?—No, that will have to be fostered, and the purchasers will have to be educated to it. The ignorance of the purchasing public in optical matters is inconceivable to those who have not happened to be, as I happened once to be, very often in the shop of an optical instrument maker. I had different instruments made for me, and I was often standing by and seeing the people come in, and I heard their unreasonable questions; they do not know what is wanted; they puzzle between the fit of the frame and the refractive power of the glasses. They are unreasonable, and they will have to be educated up to it.

409. (*Dr. Thorpe.*) I suppose you would regard as a very important feature in the work of the Kew Observatory the continuity of its magnetic work?—I believe it to be very important. That, again, is not much in my line: it is only a little in my line, but I hear it so well spoken of on all sides.

410. You have attained the position of being one of the most famous Magnetic Observatories of the world?—Yes, we have; no doubt of it.

411. And other observatories are looking to Kew practically for the supply of instruments standardised for use in absolute measurements of terrestrial magnetism?—I am sure of it. I say I am sure of it, because from all the colonies applications come, and I never hear anything to the contrary, and I hear a great deal to that effect; but on my own personal knowledge I do not profess to speak.

412. (*Mr. Rücker.*) Some foreign observatories now are taking the French pattern of instruments, but you think it would be correct to say that a very large portion of the scientific world come to Kew for those things?—Yes.

413. (*Dr. Thorpe.*) Would you regard it as an unfortunate thing for Kew if any extension of the work of standardising, such as may be contemplated by this Committee, were to jeopardise the position of Kew as a Standards department for terrestrial magnetism?—It would ruin Kew, of course. If a large institution elsewhere with large funds, and with a Government prestige, was called into existence, there would be no room for Kew.

414. I do not imply that, but I mean rather that if you were required to take on work which was inconsistent with the due performance of your magnetic work, that would be a very serious matter as regards Kew?—Clearly it would. I do not know that a Kew on a small scale could be maintained, because so much is requisite to keep any detached institution going—the attendants, for instance; you want so many people about it. When once you have got all that you can add on but you cannot diminish much.

415. Now, with respect to the certificates, I gather from what you have told Mr. Rücker that you think it is the proper function of Kew not merely to follow public opinion in demand, but to create the demand on the part of the public?—Certainly.

416. The case of the watches you consider a very important one in point?—Yes.

417. You have by offering certificates enormously improved the general average behaviour of good watches?—Yes, of high-class watches—costly watches is the better word.

418. The effect is this, then: that the existence of Kew as a Court of Reference serves to protect the high-class manufacturer from the unfair competition of instruments which, though outwardly looking as well, are, as regards their performance, very inferior?—Quite so. I may add that it is helpful to the actual manufacturer, not merely to the nominal manufacturer and seller. The highest-class watches, as I understand, are made, not many, merely two or three in a year, per maker, by individual persons in Clerkenwell, who go with their watches to well-known dealers and sell them at a high price, and then the watches pass in the name of a dealer. Now we can give, if applied to by him, the certificate to the actual maker, which is an encouragement to him.

419. Do you mean that you can give to the actual maker a certificate which he can hand on?—If the actual maker came to us with his watch we could give him a certificate, and then he could go furnished with the certificate to the great dealers and say: Here is my watch, and he could make, of course, better terms.

420. By having a certificate of this character to show?—Yes.

421. But I presume you would give your certificate to anybody who applied?—Yes, to anybody.

422. Not only to the maker in the first instance, but to anybody who chose to bring the watches?—Yes, for the watch I have in my pocket I have a certificate.

423. That happens to be my case too. You said—this is, perhaps, a correction—that you standardised opera glasses for the navy, but you meant binoculars?—Yes, you know the principle of the two instruments is the same; it is often spoken of as the opera-glass arrangement in distinction to that of ordinary telescopes.

424. (*Mr. Roberts-Austen.*) As relates to the testing of thermometers and watches, Kew is self-supporting, is it not?—Yes; everything that is standardised, as soon as it is set going, we make self-supporting.

425. (*Mr. Rücker.*) You have considered the question of the extension of Kew and the formation of a National Physical Laboratory, have you not?—Yes.

426. Have you formed any opinion as to the desirability of such a scheme?—If it is done well—yes; but if the Government interferes and rather embarrasses our work with officialism—and only does that—we would rather be left alone. There is one more thing I should like to speak about—the Meteorological Council. That Council has only lasted for twenty years; its predecessor was a Meteorological Committee of the Board of Trade ten years before. The Government took it in hand after the death

of Admiral Fitzroy. I happened at that time to have had a good deal to do with meteorology, and also to have been closely connected with the British Association as secretary, and a small departmental committee of the Board of Trade was appointed, of which I was one, and the Hydrographer and the present Lord Farrer were the other two members. Between us we settled the constitution of the Meteorological Committee, and I was one of the members of it. Then after ten years it was thought advisable to reconsider the matter, and again a committee met; it was a larger one—a treasury committee—of which I happened to be one of the members, and a large sum was thought advisable to be placed into the hands of the Meteorological Council which thenceforward took the place of the Committee; it was entirely free from Government control; the Government audited the accounts, but nothing more than that. That has been going on for twenty years. It is a unique case of Government establishing a scientific institution where the money is handed over entirely to the responsibility of the holders of it, and it is a good question to consider how far that method in which the Chairman is paid £300 a year and the members of the Council are paid according to their attendance—a total, in fact, of £1,000 a year being given to them—how far that is or is not a useful precedent in this case. My own feeling is that if you give the Chairman of the Council of Visitors—you must, perhaps, use those names—a position of dignity, which you would, and if you give him plenty of useful work to do, and work of interest, I think that could be done gratuitously. Of course, the Council must be supplied with a good secretary. I take it there would be more life in that than by handing the matter over to a single person, who would work very well at first, but whose field of operations would be so extensive that he would look to his own hobbies in it more than to the rest, and the gentleman who headed it, whoever he might be, would become more and more conservative, and there would be less life in it. Whatever management is fixed upon, I think the feeling of the scientific world, as you may judge by all their scientific societies, is, that gratuitous work of the good kind I mention can be got.

427. You believe that scientific men would be found to take control of such bodies gratuitously?—Yes, under all these circumstances, with the labours largely taken off their shoulders. I have thought a good deal about it. I am, unfortunately, quite ignorant as to the chairmen of companies where the chairman alone is paid, and considerable work is exacted from him, and therefore can give no useful opinion as to the merits or demerits of that system. But I think that if you introduce payment at all, you cannot ensure the man leaving his post when it is advisable for him to leave. I think, on the whole, the gratuitous service is the best.

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428. (*Mr. Chalmers.*) That, on the whole, is your deliberate opinion?—It is indeed. I have thought it well over. I did not mention the numbers, I should say between 50 and 100 thoroughly representative men of all interests concerned, appointed, I should say, by the Royal Society, who should at the same time appoint for the first year the first council. Then after a year had elapsed this provisional council would come with their report to the general meeting, be re-elected, or substituted, or whatever it might be, and thenceforward these general metings of the visitors, as we will call them for want of a better name, should be the supreme authority just like the committee of the British Association is.

429. (*Dr. Thorpe.*) You are familiar, of course, with the procedure as regards Greenwich?—Yes, I am.

430. May we gather that it is your conviction that something on the same lines as the Board of Visitors at Greenwich would be efficient?—I do not think it would at all. If there is a great background of scientific men who may cross question as they do at scientific societies, and to whom the council must explain themselves, then there would be a large pushing force behind which would compel the superintendent or the chairman to attend to it.

431. Yes, if that pushing force were unanimous, but then, I think, it is very likely if you widen the constituency in that way you would get it split up into several opposing camps possibly?—One knows what all popular government is, but still it is rather the genius of England to prefer, and, as I say, all the scientific societies have adopted it; they have never adopted any other that I know of, and so it looks as though precedents were very strongly in its favour.

432. (*Mr. Rücker.*) Although, of course, we are not at present discussing the future of Kew, as far as you know the Kew Observatory Committee would have no objection to this committee discussing the question of the possible union of Kew with another institution?—None.

Friday, 12th November 1897.

PRESENT:

Mr. A. W. RÜCKER, D.SC., F.R.S. (in the Chair).

Sir COURTENAY BOYLE, K.C.B.
Sir ANDREW NOBLE, K.C.B., F.R.S.
Sir JOHN WOLFE BARRY, K.C.B., F.R.S.
Mr. W. C. ROBERTS-AUSTEN, C.B., F.R.S.
Mr. ROBERT CHALMERS.
Mr. ALEXANDER SIEMENS.
Dr. T. E. THORPE, F.R.S.

Mr. L. BLAIKIE, *Secretary.*

Dr. CHARLES CHREE, F.R.S., called; and Examined.

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433. (*Mr. Rücker.*) You are superintendent of the Kew Observatory?—Yes.

434. For how many years have you held that post?—Four years and a-half.

435. I should like you to give us some account of the work done there; perhaps, in the first instance, it would be better to confine yourself to the work proper to an observatory?—The work as an observatory is partly on behalf of the Meteorological Council and partly on behalf of the Observatory standing by itself. The work for the Meteorological Council consists in running self-recording instruments recording meteorological phenomena (barometric pressure, temperature, electrical potential, wind velocity and direction, rain, and sunshine). These are the chief things. It also serves as a central station for the Meteorological Office, in the shape of giving advice on scientific matters, and examining the first-class meteorological stations. I think I may say that that is all that it does for the Meteorological Office. Then, as an observatory working by itself, it records magnetic phenomena, that is to say, it runs self-recording magnetic instruments, and standardises their readings by means of absolute observations. I think that that is, in short, all the work that is done as an observatory.

436. To take first the last point to which you have referred, namely, the magnetic observatory, do you consider the Deer Park is a satisfactory site for a magnetic observatory in all respects?—I think that it is a very satisfactory site, in so far as it is distant from any town, or railway, or source of disturbance. I am not sure that it is the best position for having a deep underground chamber for running the self-recording instruments. There may be an improvement there—I cannot say whether it is a very good site for that, as I have not any means of judging.

437. With regard to the magnetic instruments, you also there, I think, compare other magnetic instruments with your own standards?—Yes, but I regard that as coming under the head of testing work.

438. You would rather that were taken a little later, then?—Yes.

439. Then with regard to the work done for the Meteorological Council, in the first instance you say that you inspect their stations?—Yes; the first-order stations; that is to say, the stations that have self-recording instruments.

440. And you yourselves are also a station of the first-order, are you not?—Yes.

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441. Do you think it is essential that the institution which inspects the station should itself be a station?—An expert who knew thoroughly about the working of the self-recording instruments and gave his whole time to it, could do it as well as we could; but he would require to be a man who had a thorough practical knowledge of the working of self-recording instruments.

442. But if you are to do it it is necessary that either you or your assistants should be thoroughly acquainted with the working of these instruments?—Certainly.

443. To come next to the verification work which you do there, for whom do you do the testing of magnetic instruments which we have just referred to?—That is done mainly for colonial observatories and foreign observatories, and occasionally for private individuals. The great majority of colonial observatories have had their instruments verified at Kew, and they have occasionally to have fresh instruments or fresh parts of instruments verified. There are fully twenty observatories possessed of self-recording instruments which have been verified at Kew, so about half the actual observatories in the world have had their instruments verified at Kew.

443* Are they bought by the observatories subject to the condition that they should pass the Kew test?—That is so.

444. Both the self-recording instruments and absolute instruments?—Of course the number of absolute instruments is very considerably greater because some stations have had more than one. They have been also used in expeditions, and a considerable number of private persons and teaching institutions have had them.

445. So that in that case the work of verification is done not only for observatories, but also for private institutions and individuals?—Certainly.

446. In other words the whole of the trade in these magnetic instruments in England—the whole of the instruments bought here—practically pass through your hands?—Sometimes we get them sent back, because they have not passed through our hands and have not been found satisfactory. As a rule they do come back to us in that condition if they have not first passed through our hands.

447. If you have not previously tested them they are generally sent you afterwards to test?—That is so.

448. In the next place, you verify thermometers?—Yes.

449. Could you tell us for whom the largest part of this work is done?—The largest number of instruments are clinical thermometers; of these we test about 15,000 or 16,000 annually. They are generally sent to us straight by the makers, and of course we cannot always tell their ultimate destination. They are mainly for use in this country, and also largely for use in India, Canada, and the United States. Our knowledge as to their ultimate destination is only derived from the requests of makers to put on the certificates the names of the agents in foreign countries.

450. But they are sent to you direct by the makers?—They are sent to us direct by the makers in nearly every instance.

451. So that the verification in this case is desired by the trade?—Well, it may be desired by the customer, who may make it a condition that it should be a verified instrument.

452. With regard to the higher class thermometers, do you verify many of them?—Of course we verify a large number of meteorological thermometers. Perhaps the half of these are intended for use in cotton cloth factories, where, owing to a recent Act, it is compulsory to have a certificate with the instrument; I think the great majority of those instruments pass through our hands. That is a somewhat higher class of work than clinical thermometers. Of the very highest class of work—such as is done at the Bureau International and the Reichsanstalt—we do practically nothing; we could not do it.

453. With regard to cotton factories, what is the condition laid down there by the law?—I think it is specified simply that the thermometer must have been verified. Nothing, I think, is said as to the place; that is left to the discretion, I presume, of the inspectors.

454. But practically most of them come to Kew, you believe?—I believe that the great majority, if not all, come to Kew.

455. What stamp do you put on?—We put a "K. O." mark with the last two figures of the year; say, "K. O. 97."

456. (*Sir Courtenay Boyle.*) Do you put that on the clinical thermometers as well as on the ordinary thermometers?—On every thermometer that is divided on its own stem.

457. (*Mr. Rücker.*) To go back to the thermometers for the cloth factories. Do you test them in many points?—We test them at every ten degrees between 32° and 92° Fahrenheit.

458. I suppose the Act has not been passed long enough for you to get any thermometers back to re-test?—We may have had an occasional one—I think we have had a few, but I am not prepared to say.

459. Then to pass to the higher class of work, which you say the Reichsanstalt does, you hardly feel competent to undertake that at present, I understand?—We do not. Occasionally, in answer to special requests, we have done it, issuing not a certificate but a statement, stating that we shall not be responsible for its accuracy, but that it is the best we can do.

460. What are the difficulties in the way of your carrying out this work?—We have not suitable apparatus for securing uniformity of temperature, and we have not sufficient skill in the assistants to do the elaborate calibration work and to know thoroughly what such things as different scales in thermometers mean, or generally to supervise the work.

461. By having additional assistants and additional apparatus would you be able to do this work?—Certainly.

462. (*Sir Courtenay Boyle.*) Have you applied for that additional assistance?—We have made no application; we have attempted ourselves to improve the thing and are attempting to do so at the present moment, that is to say, to acquire further knowledge of our position, but we have no source to apply to.

463. (*Mr. Rücker.*) Have you any relations with the International Bureau of Paris?—We have no direct relations more than any other institution in this country.

464. Have you applied to them for standard thermometers?— We have purchased standard thermometers from Tonnelot, verified at the Bureau International.

465. Would you use them as your ultimate standard now?—I should like to be assured of their constancy. I should not accept them as an altogether satisfactory ultimate standard in view of the fact that a gas thermometer is considered such at the Bureau International in Paris and at the Reichsanstalt, and that everything is ultimately referred to that.

466. Then to standardise those, if you had any doubts about them, you would have to send them to Paris?—Unquestionably.

467. Are there any objections to that?—A delicate thermometer is not an instrument that may be very easily sent through the Custom House nor any great distance without considerable risk of damage.

468. Have any such instances of damage occurred within your knowledge?—They are very frequent.

469. To valuable instruments?—To our ordinary Kew standards going to Ireland or going to the continent it is by no means infrequent.

470. Then you do regard it as a serious drawback that you yourselves have not a gas thermometer?—Certainly.

471. What is the difficulty in the way of having a gas thermometer?—The difficulty is, first, of course, the very considerable expense of a suitable instrument; and, further, that to work it requires a considerable amount of time and scientific knowledge, neither of which is possessed at present by the staff at Kew.

472. You mean by that that it is an instrument that requires to be used by an expert?—Precisely.

473. And that you have not at present an expert on that subject on the Kew staff?—That is so.

474. Then you do not consider the fact that there is an air thermometer at Paris satisfactorily meets the difficulties of English thermometry?—I think not, not only for the reasons stated, but also on account of the extreme slowness of getting anything done; that is to say, with any delicate instrument that is sent to the Bureau, it is a question of months, if not years, before you can get the work carried through.

475. With regard to the hydrometers, I should like to know what you do for them?—We try them at different points to test their accuracy. First of all we have a series of standard solutions, which we assure ourselves are satisfactory by reference to weights and a balance in the ordinary way, and then we use these for trying the hydrometers at certain fixed points, say, specific gravities 1.04, 1.05, and 1.06 at intervals of ten degrees, so to speak.

476. Whom do you do the hydrometers for?—They are mainly for London opticians; some of them are for use, we know, by the Meteorological Office for sea-water tests; others are used for oil vessels, getting specific gravities there; and others are used, I believe, for testing alcohol by private people.

477. The hydrometers are, I believe, tested also by the Standards Office?—Yes; I believe so.

478. Do you know why some are sent to Kew instead of all being sent there?—I do not know; naturally the

meteorological ones would come to Kew through the connection with the Meteorological Office.

479. I think we need not discuss each instrument. You have put in your proof a reference to sextants and compasses—for whom do you do them?—About half of the sextants are done for the Royal Navy. All the "Britannia" cadets must have a Kew verified Class A sextant. About half, I should say, are for private people. The ships' compasses are all for the Mercantile Marine.

480. As to binoculars?—With reference to binoculars, about 90 per cent. are for the Admiralty. All their telescopes I think now pass through our hands.

481. Do you get fees for this work done for Government offices?—Yes.

482. The same fees as are paid by an ordinary manufacturer?—Or a little less for a quantity; I think they have rather a preference.

483. Then as to photographic lenses, you have lately begun to test them, I think?—Yes, for about nine or ten years.

484. There has been no very large demand for them yet, Mr. Galton told us?—Very small. I think it is purely for the want of a proper photographic test. We want really to be able to develop that test, but we have not been able to devote the time necessary to get a thoroughly good practical test which makers will appreciate.

485. Do you do any work on commission for institutions or individuals?—We do about £300 worth annually of commissions.

486. £300 of fees?—The cost of the instruments and the photographic paper that passes through our hands averages about £300 a year.

487. For whom do you do that?—About half for colonial observatories and a certain amount for foreign Governments, such as Russia and Portugal, and places that have Kew verified magnetographs or other instruments, and a certain amount for private individuals.

488. With regard to the experimental work carried on for Kew, do you train observers other than your own assistants?—Yes; a considerable number of magnetic observers pass through our hands. Most of the Admiralty people engaged in survey work who take magnetic observations, three or four a year, pass through our hands, and a good many of the British magneticians have done the same and also a few other meteorological observers, such as the present superintendents of Mauritius and Valencia observatories, I think, and one or two other places.

489. Are any fees paid for this instruction?—Fees are paid for instruction. Generally, I think, a fee of five guineas is paid by the Admiralty for each officer instructed.

490. But in the case of individual scientific workers do you charge a fee?—I could hardly speak from recollection as to that. I think sometimes they have come through the Meteorological Office, and I cannot tell what their relations may have been.

491. Have you many inquiries addressed to you as regards this work which take long to answer?—We have perhaps every second or third day such inquiries. For instance, this morning before I came I had an inquiry as to self-recording magnetographs for a Scotch station—a question requiring a very considerable amount of thought to answer properly.

492. Are those enquiries such as to lead you to believe that it is desirable that there should be a place where information can be readily obtained of this kind?—Unquestionably; in such a case as I have mentioned, without proper information, there might be a complete throwing away of £400 or £500 on instruments in an unsuitable locality with an unsuitable installation. That is very likely to happen.

493. With regard to your relations with the Royal Society, what are they?—The Royal Society administer the Gassiot Fund, consisting of the income of £10,000 left by Mr. Gassiot. It is invested in Italian Irrigation Bonds, and produces something like £480 a year. Then to see that the work is properly done they appoint a committee, consisting of twelve members of the Royal Society at the present moment, who really act as directors of the institution. They meet once a month, and anything of importance that requires a decision to be made is brought before them.

494. What is paid by the Meteorological Council for the help that you give to them?—The Meteorological Council pay us £400 a year to cover the regular work, that is to say, the observation work and the inspection work, and if there is anything special in the way of research work it is customary that a payment should be made for assistants' time, but it is not always done.

495. What do your fees for verifications amount to in the course of a year?—The fees for verification in the last five years have amounted to £9,666, or about £2,000 a year, being an increase of about 25 per cent. over the previous five years.

496. The amount of verification work is increasing, then?—It has increased very considerably since 1892.

497. Is that increase both in the number and in the class of the instruments dealt with?—It is an increase, I should say, rather in the number than in the class. The class of watches has improved; the class of other instruments has remained very much stationary.

498. You use the word class in the sense of standard?—Yes.

499. You mean not only in the number but in the variety of the instruments that you deal with?—Yes. For instance, binoculars and telescopes were not verified until eight or nine years ago, and compass tests for ships' compasses have been completely reorganised within the last year, and photographic lenses are comparatively new.

500. Then in all probability your income from that source will be an increasing one?—The chances are it will.

501. Is the institution self-supporting with the endowments that you have mentioned?—It is quite self-supporting; that is to say, within the last five years we have really had a surplus of three or four hundred pounds a year after paying what is absolutely necessary to carry on the mere verification work.

502. For what do you regard your surplus as available?—I regard it partly as a safeguard against a very probable diminution of the Gassiot income. I do not regard that as a very safe investment. It is showing a tendency to drop. I also regard that surplus as a means of making investigations in thermometry and other departments that require it badly.

503. (*Sir Courtenay Boyle.*) I am sorry I missed your answer as to how it was invested?—It is invested in Italian five per cent. Irrigation Bonds.

504. (*Mr. Rücker.*) Supposing any additions were required to the buildings—I believe there have been such additions in the past—who pays for them?—The observatory has paid for these out of its own pocket.

505. Although the Government supplies the building it has not provided funds for additions to it?—No.

506. But when the additions are built does the Government undertake the painting and repairs?—The Government has undertaken to do the external painting of the additions to the observatory itself. We had an addition costing about £550 about five years ago, and that the Government has taken under its wing; but additions made outside, separate buildings, the Government does not take under its wing at all, but expects us to do everything there.

507. Has this balance enabled you to do anything towards improving your thermometrical, or any other work recently?—During the last year we have arranged for a comparison of the scale of the platinum thermometer with that of the hydrogen thermometer at the Bureau International, and out of the balance I have spoken of all the apparatus has been provided and a subsidy for the observer. That has practically taken up the whole of the spare income during the last year.

508. Is he carrying on the work now at the present moment?—At the present moment he is.

509. With regard to the platinum thermometer, would you tell the Committee exactly the conditions under which the necessity for investigating them has arisen?—Well, I think that the necessity arose from the fact that at high temperatures the mercury thermometer is no good. Of course, you can get a mercury thermometer now up to 500° Centigrade by using gas under high pressure at the top, but above that it is no good, and it has been felt that it would be very desirable to have some means of taking the temperature at a higher range, and it was partly on that account that the platinum thermometers, I think, were undertaken. It was also felt, as very great claims were made for the accuracy of these instruments, that it was as well that the matter should be investigated by an independent authority, so that that was the other motive for setting up the installation. For ordinary temperature work we used to test their accuracy as regards the fixity of the zero.

510. (*Mr. Roberts-Austen.*) Have you used thermo junctions at all; have you been applied to to calibrate thermo junctions?—No; we have no experience of these.

511. (*Mr. Rücker.*) The platinum thermometers have been lately investigated a good deal by individual scientific workers, have they not?—Well, both Professor Callendar and Mr. Griffiths and Messrs. Heycock and Neville have done a great deal of work with the proper platinum thermometer, and at the German Reichsanstalt experiments have also been made under conditions which

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Professor Callendar and Mr. Griffiths hold to be unsatisfactory. That is, so far as I know, the chief work that has been done with these, except some work at low temperatures done recently in America.

512. They have been really brought to the front lately by English workers?—Certainly.

513. Do you think it desirable that some independent opinion should be obtained as to their value in this country?—Yes.

514. (*Mr. Roberts-Austen.*) You are aware, I suppose, that thermo junctions are widely used throughout the metallurgical districts in connection with furnaces?—Of course, I know that they are considerably in use—I do not know how much. The le Chatelier, for instance.

515. (*Mr. Rücker.*) To come back to the question of the balance of which you have just been telling us how some is spent; do you think that balance of £300 or £400 a year is enough to increase the work of the Observatory to a sufficient extent to meet all the demands which might legitimately be made upon it?—No, I think not. For one thing, we are absolutely uncertain that the balance will continue. If there were a drop, say, in clinical thermometers or in anything else, we might find after undertaking a serious piece of work, that we had no funds to carry it out. There is such a feeling of uncertainty with regard to the future that one hesitates to attempt anything large. It is also, in itself, an absurdly small sum to apply to experiments in more than one direction at a time.

516. And if that balance were to go this country would not have any institution where work of this kind could be undertaken?—Not so far as I know.

517. To pass on to the next subject. Perhaps you will just tell us briefly what the staff of the institution is?—The staff of the institution consists of a superintendent, a chief assistant, then there are four first-class assistants, three second, and six boy clerks, and, of course, there are a caretaker and housekeeper.

518. With regard to the first-class assistants, would you call them highly-trained scientific workers?—They are not scientific workers, except in the sense that they have had a long experience in the use of scientific instruments. None of them have received any training beyond what an intelligent boy entering the observatory at fifteen or sixteen years of age might be expected to have. They are very first-rate men of their class—I do not think one could have better assistants of their class; but they are not scientifically trained men.

519. Have you ever received suggestions from instrument makers as to the desirability of extending your work?—Yes; we receive from time to time suggestions.

520. Could you give me any specific instances?—We have had suggestions with regard to testing ships' lights from three or four different sources, from makers, and from private individuals.

521. Do you know what the nature of the tests required for ships' lights would be—do they want testing?—I should say they want testing as regards the goodness of the glass through which the light passes, and the strength of the light. These, I think, are the main qualifications.

522. (*Sir Courtenay Boyle.*) Please develop that a little bit more; what do you mean by the strength of the ship's light. Does that mean the size of the wick?—I mean the candle power.

523. Is it by the size of the wick, or how is it that you test the candle power?—It is not one of the requests that we have conceded.

524. You have not done it?—We did not feel that we were capable of doing it with the present staff.

525. (*Dr. Thorpe.*) What I gather was asked for was the photometric value of the light?—That is so.

526. (*Sir Andrew Noble.*) That does not extend to electric lights, I suppose, for instance, the arc lamps for search lights?—We have had no special inquiry about search lights. I think it was ordinary ships' lamps.

527. (*Mr. Chalmers.*) Was it a question, may I ask, of whether the work would be remunerative, that stopped you from undertaking it?—It was; that is to say the prime cost of setting up the suitable apparatus seemed to be rather deterrent.

528. (*Mr. Rücker.*) Is there any room in which you could do anything of that sort now?—No, I do not think so.

529. It would have meant building?—It would mean building.

530. Have you had any other applications of a similar kind?—Applications to test glass, that is to say, glass for gauges and things of that sort; applications to test viscometers, and polarimeters.

531. One thing at a time; as to the testing glasses for gauges, whom did they come from?—The request came from Messrs. Moncrieff, of Perth. One of the firm called upon me personally, and discussed the matter, and made a great grievance that he could only get it done at Charlottenburg.

532. He would desire it to be done in this country?—He said he would very much prefer that it should be done in this country.

533. I think you said you had applications to test viscometers?—Yes.

534. Where did the application come from there?—That came from Baird and Tatlock.

535. That you were obliged to refuse also?—That we refused also.

536. Then as to polarimeters, have you had any applications?—The applications for polarimeters came from Harris and Co.—both polarimeters and saccharometers.

537. (*Dr. Thorpe.*) To go back for a moment to the oils. I suppose it was with a view to determine their lubricating value that the application was made?—It was before I came to the Observatory, so I cannot speak with certainty; I should say it possibly was.

538. Have you had more than one application to determine the lubricating value of an oil?—That I could hardly say, unless it went before the Kew Committee, and if one inquiry went before the Committee, and was repelled, I could have no means of finding out without searching through all the letters how many others there might have been.

539. (*Mr. Rücker.*) Is there any other assistance that you are able to give to instrument makers?—For instance, we have tested the constancy of zero in thermometers treated in particular ways, and we have occasionally investigated the properties of magnetic steels, and we very frequently give makers information on such points as the relation of the yard to the metre, and general information of that sort.

540. (*Dr. Thorpe.*) You say "With regard to thermometers treated in a special way," you mean that instrument makers have come to you to test the results of experiments which they have made with the view to getting a constant capacity of bulb, is that so?—That is so; and they have also come to us to make investigations as to the qualities of new glass that they have themselves devised and not tried.

541. (*Sir Andrew Noble.*) As to the qualities of what? New kinds of glass.

542. (*Dr. Thorpe.*) For thermometers?—For thermometers.

543. (*Sir Andrew Noble.*) In which there have been so many improvements made in Germany?—Precisely.

544. (*Mr. Rücker.*) Have those inquiries been recent?—Some of them have been recent; others have been at intervals during the last ten years.

545. Have you always been able to undertake those investigations?—No, we have generally tried to do something, but not nearly so much as we should like to have done.

546. Is it not the fact that the Bureau International have selected a French glass as the test for thermometers?—The Bureau International have selected the French *Verre dur* for their standard glass. I think now they are hesitating over its advantages compared with Jena glass for high range thermometers.

547. The Reichsanstalt selected the Jena glass, did it not?—Certainly.

548. Do you think there would be any advantage in having an English institution in which English glass could be independently tested?—Most unquestionably, because for one thing, unless we know that English glass is of uniform composition, and has a uniform natural temperature scale we are very much at sea as to what the value of the corrections given to the thermometers is. We do not know what scale we are giving the corrections on.

549. And that work would require a long time?—It would require a very considerable amount of research before one could feel at all sufficiently satisfied with the results.

550. What should you say were the main wants of the Observatory now?—I think that the first—the chief want—is the means of a very close scientific study of thermometry, that is to say, to know exactly what the scales are with which we are dealing, and an attempt to make the information that we are giving our instrument makers more useful for really high-class work. At present we cannot do that. That is the first thing I should consider necessary. Then I think with regard to optical work that we are very defective. This testing of lenses, as I mentioned before, has not come to very much, largely owing to the fact that we have not been able to give the

thought that is necessary—we have not been able to devise a very good photographic test, and we have not been able to win the confidence either of the makers, or of the public. That, I think, we could probably do if we had more skilled scientific work in the Department.

551. Taking the first of the things referred to the Committee, namely, the testing and verification of instruments for physical investigation, you do something, at any rate, but you feel that with greater means you could do it more satisfactorily?—We could do the higher class work very much more satisfactorily with further means.

552. (*Mr. Chalmers.*) Would you say there is much demand for that higher work?—Most of the physical laboratories in the country require several high-class instruments of each kind, and there are now a very considerable number of those laboratories, and the number of physicists is increasing, and they must all get their instruments from somewhere.

553. (*Dr. Thorpe.*) Is it not the fact that those gentlemen practically all go to Germany now?—I believe practically all.

554. (*Sir Andrew Noble.*) Because they cannot get them in England?—Yes.

555. (*Mr. Chalmers.*) That would be for scientific rather than industrial purposes, the extension you are speaking of?—Yes, but even some of the industrial purposes, especially for high temperatures, require a considerably greater accuracy than is given by an ordinary English thermometer. It may be 10 degrees out, at a high temperature, and yet seem all right within the range that we can test directly.

556. (*Mr. Roberts-Austen.*) If an English variety of glass were available for thermometric work would that lead to a material development of British industry?—I think it would very probably prevent the British industry being cut out by the Germans.

557. (*Mr. Rücker.*) With regard to lenses, to come back to them: the lenses are tested not merely for scientific purposes, but they are lenses for ordinary photographic cameras?—Yes, I think that in the meantime we are really made use of by instrument-makers who have got a new kind of lens in hand. A considerable number of those new Jena glasses that the makers feel in doubt about they send to us. It is more for that class of work at present than for the general public that we are used.

558. (*Mr. Chalmers.*) Do you anticipate that the ordinary clinical thermometer might under present conditions if they continued be driven out? I may say the ordinary clinical thermometer, as distinguished from the highest thermometers required for scientific purposes pure and simple?—It is largely a question of public confidence. The German ones are, on the whole, rather cheaper, and if the public came to regard them as equally satisfactory it might very certainly lead to the displacement of the English trade.

559. On the price alone even?—On the price question.

560. (*Dr. Thorpe.*) With respect to clinical thermometers, you know it is a fact that our English-made clinical thermometers enjoy the highest reputation of all clinical thermometers even in Germany?—I think so far as I can judge the workmanship is rather superior. I think they are on the whole better than the average German clinical thermometers that I have seen.

561. Now that excellence in the clinical thermometer has been very largely induced by the action of Kew, has it not?—I think so, but that is a matter on which I may be prejudiced. An instrument-maker would, perhaps, be less prejudiced.

562. (*Sir Andrew Noble.*) May I ask if you have ever had any application to test thermometers for calorimetric experiments which are graduated to a very small division, such as the hundredth of a degree or the thousandth of a degree Centigrade?—I had an application last year to test one divided to thousandths of a degree. I have had several applications to test them divided to hundredths. That I have attempted to satisfy by issuing a statement, not a certificate of the results.

563. Were they made in this country?—In Germany. I have tested some made in this country, intended for underground temperatures, divided into hundredths.

564. Not divided into thousandths of a degree?—No; hundredths.

565. (*Dr. Thorpe.*) These thermometers to which you now make reference are thermometers which are largely used I believe by chemists in cryoscopic work?—I believe they are mainly used by chemists.

566. And that is a method which practically took its rise in France and in Germany?—I daresay. I know nothing personally of that.

567. The thermometers which are used for this particular class of investigation are practically all made in Germany?—I should judge so by the nature of the scales.

568. They are usually the German form of thermometer, are they not?—They are the German form of thermometer almost universally.

569. (*Mr. Rücker.*) Do you do anything for the construction and preservation of standards of measurement at Kew?—Of course we make standard thermometers. We have made perhaps 700 of those during the last fifty years; that is the only kind of standard instrument that we actually make.

570. Then, on the third point, for the systematic determination of physical constants and numerical data, are you able to do anything on that outside the magnetic work?—Or the meterological work?

571. Yes?—I should think not.

572. So you only come under the head of the first of these three things, the testing and verification of instruments to any very great extent?—Mainly, yes.

573. (*Sir Courtenay Boyle.*) Who are the trustees of the Gassiot Fund?—The Council of the Royal Society.

574. Do they audit your accounts?—Their auditor, Mr. Keen, audits our accounts.

575. Through a committee?—No; they have a regular accountant.

576. But the regular accountant reports to the Committee of the Council?—I believe so.

577. Do you get your land and buildings from the Government?—We pay for the land £3 an acre; the buildings we have at a nominal quit rent of 5s. That is what we get from the Government.

578. That is less than the ordinary market price of the land, is it not?—No; it is rather more than they charge the Golf Club in our immediate neighbourhood, so I should say it was the average market value.

579. (*Mr. Chalmers.*) Is it not a fact that an observatory was handed over—it used to be a Government observatory?—It used to be a Government observatory, and was then handed over to the British Association.

580. And that is the main building that you occupy?—That is so.

581. (*Sir Courtenay Boyle.*) You said that you have made a good many standard thermometers; would you mind telling me what you mean by a standard thermometer: is there any such thing as an absolute standard thermometer?—It means that you take the thermometer and after determining the freezing point and the boiling point you sub-divide the bore into exactly equal volumes. That is what one knows as a standard thermometer, so that you ensure if the glass is perfectly uniform that you are measuring on a fixed scale. That is a scale, of course, differing from that of an ordinary gas thermometer; and one of the things that I think important is that we should know exactly how that scale stands to the gas thermometer.

582. (*Sir Andrew Noble.*) Do you when you are correcting give the correction from your mercurial standard thermometer, and is that standard corrected to the gas thermometer?—We do not attempt that. The only sense in which it is corrected to a gas thermometer is that for very low temperatures we put thermometers in freezing mercury and tell the makers the reading, telling them that on the air thermometer the reading ought to be so-and-so. That is all the reference we make to a gas thermometer.

583. In testing your thermometers for meteorological purposes, how low do you go?—We go down to 12° Fahrenheit in the case of ordinary minimum thermometers, and to 0° Fahrenheit if asked to do so.

584. To zero Fahrenheit?—Yes, and in special cases when asked we go down to the freezing point of mercury —minus 38o; that is to say, we have nothing between zero and minus 38o.

585. Your scale is divided upon the scale between zero and 100o, taking the centigrade scale—I mean is it a uniform division?—It is now a uniform division, but a matter of twenty or thirty years ago, after Balfour Stewart's determination of the freezing point of mercury, a good many thermometers were sent out in which the freezing point of mercury was taken as a third fixed point, so that you had one scale between freezing water and boiling water, and a totally different scale between freezing water and freezing mercury. That the Committee no longer sanction.

586. So that the old ordinary thermometers used at low natural temperatures were frequently seriously out?—They frequently were ridiculously out, but not on account of the practice just referred to. The difference between the air and glass-mercury scales at the freezing point of mercury is only of the order of half a degree Fahrenheit.

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537. I once was connected with a meteorological observatory at Canada, very many years ago, and at 30° below zero, the thermometers varied as much as two or three degrees, and I got from Kew at that time two or three thermometers which were a very great improvement, the variation between them being very small; I got a standard thermometer from Greenwich, but I had no means of determining whether it was actually correct or not, and at Greenwich they did not pretend to say it was. Now, if you had the gas thermometer at Kew, you would be able to determine all these points for yourself—Certainly.

538. (*Sir Courtenay Boyle.*) Your standard thermometer that you refer to is a mercury thermometer?—A mercury thermometer, we have no standard but the mercury.

539. There is no other standard thermometer as far as you know?—We have not any other. Of course, at the Bureau International they have a hydrogen standard, and at the Reichsanstalt they use air.

590. There are many glycerine thermometers, are there not?—Yes, spirit and glycerine.

591. Is there any standard of them so far as you know? We refer them all to the freezing point of mercury.

592. So it is only by reference to that that you can really test the glycerine thermometer?—At the present moment I have some for a polar expedition, but some differ by degrees from the others.

593. Would you describe as your work the testing and verification of instruments—not the verification of standards at all, but the testing and verification of instruments?—Some of those instruments are standard instruments; for instance, standard magnetic instruments or standard thermometers.

594. When you say "standard," will you explain to me what you mean by standard; it is not a statutory standard, is it?—No, there is no statutory standard at all in temperature or in magnetism; it only means that it is a self-contained instrument, which is the ultimate authority for its own readings.

595. Of course, you are aware that in measures there are statutory standards?—I understand that, except that the standard temperature of 62° Fahrenheit has not yet been defined.

596. When you refer to standard you mean that it comes up to a recognised value, that is all you mean by "standard"?—It is rather that it is a self-contained instrument, whose corrections are given, not by reference to anything higher than itself.

597. That is a good definition. Are the instruments which you test intended for physical investigation or for industrial purposes?—The great majority are for industrial purposes, the small minority are for physical investigation.

598. Do you think it is an advantage that instruments for industrial purposes should be tested by a State body?—I think that so long as the body is thoroughly respectable, and wins the confidence of the public, it does not so much matter whether it is a State body or whether it is not.

599. It would have to take the utmost possible pains to safeguard its stamp, would it not, if it was a State body, and to prevent the forgery of its stamp?—I do not think there would be more danger of that with a State body than with a private testing institution; with the State body there will be more apprehension, on the part of makers, of the dangers incurred in forgery than with a private institution.

600. Would it not be urged that it is the duty of the State to see that its own marks are not forged, and that it is the duty of the State to institute prosecutions for the forgery of its own marks?—I certainly think that it would be the duty of the Kew Committee to prosecute in the case of forgery, if anybody would have to prosecute.

601. Are your marks not forged very often?—I think not. I am only aware of one instance which came before us, and that was very summarily dealt with.

602. By yourselves?—By the Committee.

603. Take the marking of clinical thermometers, would you be prepared to say that your mark is never forged?—There would be a very great danger to anyone in forging it, because there would be a considerable chance of the instrument being sent to us on a subsequent occasion to verify, and we should then find that it had not previously been sent to us.

604. Do you know under what statute you prosecute for putting on "K. O.," or whatever it is?—I do not know.

605. Has it been perfectly easy to get a conviction for the forgery of a mark—a voluntary mark, mind you?—I am not a lawyer, so I should not like to hazard an opinion.

606. You have had some experience of it in practice?—There was only the one case, and that was before my time as superintendent.

607. Take clinical thermometers; is it not the case that an enormous amount of absolute rubbish is sold and floods the English market at the present moment?—My experience is really limited to those that pass through Kew Observatory. I ought to mention, perhaps, that there was one case recently, it was the case of some German thermometers. A combination of makers purchased those, and sent them to the Kew Observatory; they were marked "half-minute" clinicals. They sent them to the Kew Observatory, and we verified them, and found they were "three-minute" clinicals. The sellers of these were dealt with in the Police Court, and fined £10. That is the only instance in which I myself have taken any part.

608. Just tell me again what is the mark you put on a clinical thermometer?—"K. O." monogram and the two last figures of the year, "96" or "97."

609. Supposing I choose to put on my clinical thermometer "K. O., 96," how do I commit an offence; you have no monopoly of the letters K. O., so how do I commit an offence by putting "K. O., 96" on my thermometer and selling it?—I suppose it would be regarded as fraud by leading a customer to suppose it was a Kew-tested thermometer.

610. (*Mr. Roberts-Austen.*) You said it was a monogram—a peculiar mark?—Yes.

611. (*Dr. Thorpe.*) Has the Committee at Kew taken any steps to protect this as a trade mark?—I think that they had advice on the question, and, after hearing the advice, they considered that the protection already existing was sufficient.

612. (*Sir Courtenay Boyle.*) Pray understand me. I have no doubt I am wrong, but I only want to find out how I am wrong?—It would probably work this way, that any maker who sold an instrument of that kind could not get any more instruments verified at the Kew Observatory.

613. But it is not the maker, it is the retail trader that one is afraid of, that is the difficulty. The goods pass out of the hands of the maker, and get into the hands of the retail trader?—I should think the difficulty of putting it on would be rather more than the difference in price between an ordinary thermometer and a Kew verified one.

614. (*Dr. Thorpe.*) Is it not the fact that the price (the whole thing that is entailed) is a sufficient safeguard; it is not worth a man's while, is it, to run this risk in order to avoid the small fee which Kew requires?—I agree.

615. (*Sir Andrew Noble.*) I think you said in your evidence that you occasionally sent your standard to Paris. Do you send your standard to Paris to be compared with their gas thermometer?—No, what I meant was that we have purchased three or four French thermometers which have been verified at the Bureau—we have never sent them back.

616. You have purchased them?—Yes, we have purchased them.

617. In standardising, if I might use the expression, English thermometers submitted to you, you do not use the corrections that gas thermometers indicate?—No, we refer any ordinary English glass thermometers to our own Kew standards made of English glass. In the case of a few special physical investigations I have given corrections to the hydrogen scale, using the French glass thermometers; but I have not issued a certificate. I have only done it, as it were, as a special favour to a scientific man.

618. In other words, your scale is just the division between the freezing and boiling point, a uniform division, always having regard to the calibration of the thermometer?—Yes, that is so.

619. Do you compare the thermometers so as to take any note of the difference in the thermometers rising or the thermometers falling; I mean for meteorological purposes, if they are delicate ones?—We always take readings with the temperature rising, we do not attempt to take them ever with the temperature falling; we find it rather too uncertain.

620. In that case would you not warn the user of the thermometer for meteorological purposes. Of course, for physical experiments you would always take the temperature if possible with the thermometer rising, but in meteorological observations the thermometer is falling as often as rising?—There is this difficulty: that if you expose the thermometer to a higher temperature than what you intend to give the corrections for, then you shift the zero.

621. No doubt, but suppose you leave the thermometer standing for some time that corrects itself slowly, does it not?—No.

622. Not altogether, but very nearly it comes back, does it not?—No, there is a temporary effect as well as a permanent one.

623. That is exactly what I am saying, but with good glass, that correction is reduced now very low, if I remember right?—I am sorry to say that with ordinary English glass it is a question of 1-10th or 2-10ths of a degree, if it is exposed to a high temperature.

624. It is said of the later specimens of German glass that the permanent error arising from the cause you have mentioned is but small?—With what they call glass 59^{III} the uncertainty is about .02 of a degree centigrade at any point between 0o and 100o, but with ordinary English glass, when you get up to 120o Fahrenheit it may be a 10*th*—it may be.

625. Do you have any hygrometers submitted to you, except the ordinary wet and dry bulbs?—Occasionally I think we have had hair hygrometers, of Richards pattern. but that I am not positive of.

626. But now you have mentioned it, do you know Regnault's pattern of hygrometer?—Yes, but that, I think. is very much gone out; I am not prepared to say that we have had any of those for a large number of years. I do not believe so.

627. They do not use Daniell's hygrometers?—No; that hygrometer is in the same position as Regnault's; we have had none.

628. Regnault's is far more accurate?—I believe Regnault's is more accurate than Daniell's, but they are too expensive for ordinary users, I think, and there is too much trouble with them.

629. Do they go still entirely by the Greenwich factors in determining it, because you know the Greenwich factors under different conditions give considerable differences in the dew point?—The Meteorological Office have a revised set of Glaisher's tables. They are improved, that is to say, they use newer values for some of the constants, but they are practically Glaisher's tables, with a few changes.

630. You get the actual dew point with Regnault with due care, but with the wet and dry bulb you cannot be sure of the amount of moisture, because the wind alters considerably the indication of the difference between the two bulbs?—I have been told by factory inspectors that what they consider the most serious thing is the ventilation question. Of course, we have no special self-ventilating thermometers in use in this country: they are used in Germany, and I think in the mills they have a suspicion that in the absence of the self-ventilation they do not always get what they should get.

631. In other words, the use of hygrometers, using the word in the proper sense, perhaps is not considered of much importance now, at all events, they are not submitted to you?—I think that there are very few Daniell's or Regnault's hygrometers in use at all. I think it is nearly all the wet and dry bulbs.

632. My contention is that the dry and wet bulb must necessarily give a doubtful result?—The Meteorological Office investigated the matter some years ago.

633. What is done in the case of hygrometers?—What is really done is that we test the accuracy of the thermometers as thermometers; we do not fit them up as hygrometers, feeling that so much depends on the kind of muslin and the way in which it is applied locally. We do not attempt that, we simply test them as thermometers.

634. And practically, I do not mean to say exclusively, as you have explained, but practically, the only hygrometers used in this country for meteorological purposes are the wet and dry bulbs?—Yes.

635. (*Dr. Thorpe.*) Following on Sir Andrew's question, practically the Inspector cannot get through you a certificate as to the efficacy of any hygrometer?—He cannot get any certificate through us except as to the accuracy of the thermometers.

636. Which is not the same thing as the validity of the thing as a hygrometer?—Precisely.

637. (*Sir Andrew Noble.*) You would regard it, I suppose as of great importance to the efficiency of Kew Observatory, or, at all events, in connection with physical enquiries, if you had like Paris a hydrogen thermometer, a gas thermometer?—It would make the place self contained, as you could at any time refer anything in doubt to it. I should say it was of very great importance.

638. Then you referred to the point that Mr. Rücker referred to, of photometric observations; would you have much difficulty (I speak from personal want) in giving a certificate, if you were provided with a proper staff, and proper means of carrying out the experiments for determining such things—as to the efficiency of ordinary ships' lights (steamer lights), and also electric lights such as search lights, determining the candle power; or would you with regard to arc lights prefer to do it by means of an electrical standard, say the number of Watts?—I should think that in the case of a very powerful electric light it might be a question as to whether it would not require a very extensive area to test it under natural conditions. You would want rather the carrying power depending on atmospheric conditions, but I presume it could be tested like anything else.

639. (*Sir Courtenay Boyle.*) If you had the proper staff could you determine the efficacy of a light by reference to a normal candle?—I think that the proper staff would require the presence of a man who could answer that question. I have had no personal experience in photometric apparatus.

640. Then when you have been examining ships' lights, it has been with reference to the glass, and as to what—the power of the wick, or what?—Of course, that was only a suggestion which the Committee did not fall in with.

641. And you have not examined them?—We did not examine them. The only experience we have of the kind is with the photographic lenses in comparing intensity at different angles.

642. Have you had any experience of the standard candle?—None.

643. So that you cannot say whether the standard candle is a standard photometer or whether it is not?—I cannot speak to that.

644. (*Sir John Wolfe Barry.*) You said that you wanted a gas thermometer, but that you were debarred by the cost. What would be the cost?—I really could hardly say. I should think it would probably be for a thoroughly good one several hundred pounds, and then there would be an assistant who was qualified to deal with it. I really have not considered that.

645. Would it be £1,000, or something of that sort?—I should think it would not be so much as that; I should think more likely £300 or £400.

646. And then the cost of the staff to manage it?—Yes.

647. When you have added to the buildings at Kew, has it been added out of the surplus income?—Yes, we have spent about £700 on buildings within the last seven years.

648. You said that you occasionally had to refuse investigations on account of the expenditure of time. I suppose that means the expenditure of time with the present staff?—Yes. it means practically that if any investigation has to be done I have got to devise the means of doing it myself, but I cannot do more than one or two things at a time; it is really that sort of difficulty.

649. Therefore it means that if you have to refuse for want of time, it means that you refuse for want of the adequate staff acting under you or independently of you?—That is so, largely; but also partly for this reason, that the existing staff is just about capable for dealing with the ordinary routine work, and that if any other work is undertaken it can only be done by fits and starts, when there is a slack time in the testing work.

650. I think you said also that you occasionally had to refuse to undertake work for mercantile purposes, is not that so?—Yes, for several classes of instruments.

651. Is it true that a refusal of that kind would soon become known in the particular trade, and, therefore, you would not get any more requests on account of your having made one refusal?—I should think so, certainly.

652. Therefore, it would not be right to take a single refusal as any indication of the real demand?—I think not.

653. May any individual ask for his scientific instruments to be standardised at Kew?—Yes, any person may have instruments verified there.

654. Whether he is a manufacturer or a private individual?—Yes, it is all the same.

655. They are all treated on equal terms?—They are all treated on equal terms.

656. (*Mr. Roberts-Austen.*) I understand you to say that you have no porcelain bulb air thermometers in use in Kew?—We have nothing whatsoever of the kind.

657. Do you consider that your pyrometric work should be materially extended at the Observatory?—I certainly think that it ought to be extended very materially in the direction of accuracy and of high temperature work.

658. In view of the fact that metallurgists are now very anxious to ascertain the temperatures of their furnaces and of their hot blast mains, probably the applications for verification would be considerable if you were in a position to undertake them?—I fancy that they might;

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it is not a matter in which I really have very accurate means of judging.

659. (*Mr. Chalmers.*) Have you had any applications of that nature?—We have had several applications from instrument makers.

660. (*Mr. Roberts-Austen.*) With reference to high temperature work?—Yes.

661. (*Mr. Chalmers.*) You have already had such applications?—Yes.

662. Your general disposition would be, I presume, to take on work if you saw it was of any extent, and, therefore, through fees likely to pay. Am I right in that?—Yes, you are.

663. That is to say, practically, that you have grown up—you are a department of the Royal Society, and you have seen your way to meet the demand from without?—That is mainly so.

664. Do you take it that your position would have been in the slightest degree better if you had been a Government Department; do you think to-day that it would be any advantage to substitute for your "K. O." some Government symbol with a crown on the top, in the eyes of the public, and of manufacturers?—I think there would be a distinct advantage in having some body to fall back upon that could supply funds for investigation.

665. Do you suppose that it would be of any value in the minds of the public; would it give any increased value to your "K. O."?—I think that a good many of the public imagine that "K. O." is a Government symbol at the present moment, and that is partly how it carries so much weight as it does.

666. You spoke about investigations that you would like to carry on, or that you would like to see carried on. Do you have any work carried on at Kew by people receiving any part of the grant which the Government gives to the Royal Society for the special purpose of encouraging research?—We have had several instruments purchased through that grant, application having been made by the Committee simply as a whole. We have had several grants of that sort.

667. (*Mr. Roberts-Austen.*) For instruments?—For instruments.

668. (*Dr. Thorpe.*) From your experience as Superintendent at Kew Observatory would you say that any considerable extension of the industrial side of the work of the Observatory would be incompatible with its scientific development?—I think not, so long as there was an adequate staff for dealing with both.

669. You have not found, as a matter of practice, that there is any incompatibility between the two branches of its activity?—I think that it is very desirable indeed that they should go on together, because there are often points in the practical work that require superior theoretical knowledge, and we are frequently in want of information of that sort.

670. You made some remark about the character of the underground room in connection with your continuous recording instruments. May I take it that you regard the work of Kew on terrestrial magnetism as a leading feature in its work?—Certainly.

671. And you would regret if any extension of its industrial side were to jeopardise the accuracy or continuity of its magnetic work?—Certainly, I should be sorry that it should jeopardise it, or that it should suffer.

672. With respect to the room, is the position or the character of that underground chamber such that the value of the self-recording instruments is in any way impaired?—It makes it very much more difficult to get good results; the place ought to be at a sufficient distance from moving objects, and it ought to possess a more uniform temperature than our present chamber can possess. It suffers in both of those respects. That means that certain of the records are much more difficult to deal with than they would be in one of the modern chambers.

673. Can you conceive of any practicable alteration in locality which would give you a better advantage in that respect?—I think if it were put a little distance from a building and protected in the same way as the places now at Potsdam or Washington are that the results would be decidedly superior.

674. For instance, you do not contemplate its removal from the immediate neighbourhood of the Observatory?—No. I do not.

675. You do not think there would be any advantage in removing it?—I think there would be quite a disadvantage.

676. Could you of your own knowledge say that any very considerable development of Kew, as it is at present carried on, is demanded—is there a public demand for any extension? I do not mean now and again an individual application, but is there something in the nature of a serious public demand for its extension?—I can only judge from the inquiries made with respect to the different classes of instruments being verified. Of course, we have applications to test things, and we have also inquiries whether we do test things: of the latter I have made no record. We have a very considerable number of these.

677. You mentioned, for example, hydrometers, that is a class of instrument for which I presume there is a considerable public demand for the standardisation of?—I believe so; we standardise a very considerable number of them; in the last two years, about 650.

678. Now what is the class of hydrometers, mainly those that give direct readings of specific gravity?—Yes.

679. Not Sykes's hydrometer?—There are a considerable number of Sykes's, too.

680. That are sent to you?—Yes, that are sent to us.

681. By whom are they sent?—They are almost all sent by instrument makers.

682. And you issue with those a certificate?—We issue a certificate, stating the readings or the departure from the nominal reading at the several points.

683. That is you have an absolute Sykes hydrometer?—We have an absolute Sykes hydrometer, and we also have a balance, of course, for absolute determinations.

684. How have you arrived at that Sykes's hydrometer as an absolute Sykes?—That I could hardly say; it is not a part of the work that I personally have devoted much thought to.

685. How many of such hydrometers do you get in the course of a year?—I cannot say; the total number of hydrometers during the last twenty-two months has been 650, but I cannot speak as to particulars of the classes in which they are.

686. With respect to the standard thermometer, I take it that in an absolute sense you have no standard thermometer at Kew?—We have no one that is more a standard than another.

687 When I say in the absolute sense I mean with reference to a natural scale?—No, they are really looked upon as all equal; that is to say, when they are divided out in that way, in equal volumes, we consider one is just as good as another, that is to say, we have no one to which to refer the others.

688. Yes, but those are only comparable amongst themselves?—They are only comparable amongst themselves.

689. They would not be comparable with thermometers of another pattern made elsewhere?—Well, so long as the other pattern was of the same glass.

690. Quite so, but that may or may not be the case?—That may not be the case. Of course, our thermometers are practically, you may take it, one glass.

691. That is to say, they are flint glass?—They are Powell's glass.

692. Then these flint glass thermometers, I take it, have not been systematically compared with either a hydrogen or an air thermometer?—No, we have made certain comparisons with the French *Verre dur* thermometers, but we have not been able to go to anything like the accuracy that the *Verre dur* is supposed to lead to.

693. What you lack, I suppose, is an absolute comparison of the flint glass thermometer with the hydrogen standard; you want, yourselves, to make comparisons?—We do.

694. In order to enable your degrees taken on all flint glass instruments to be referable to an absolute natural standard?—And to make sure that the different standards nominally the same, are really not different.

695. That work you have not been able to undertake?—The comparison with the French glass thermometers I do not regard as final; it was more to give one an idea as to what the probable uncertainties are than as to what the differences really are; that is to say, as showing more or less the probable error we are likely to have.

696. The cost of such an installation is not altogether limited to the initial cost of the instrument and the cost of the assistant?—I should say that the cost of the assistant was much the more important.

697. There is also, I presume, the cost of room. Would you have the means as you are at present at Kew to undertake such work?—I am not prepared to say that we could not displace other testing work and make room for an air thermometer. That I think we possibly could do, but I am not sure about it.

698. It would require the displacement of something? It would require the displacement of something.

699. (*Mr. Siemens.*) I would only ask a sort of general question: Has it not occurred to you that some further

investigations are called for? I mean when you test those instruments you find some points which ought to be elucidated, even if their immediate application to commercial matters is not apparent?—Certainly, for instance, in the case of mercury thermometers I have found now with certain Kew standards that the depression of the zero is not the same, although the glass is nominally the same, and that it varies in a peculiar manner. I should like to know exactly what the law of these variations is, so as to warn people not to use the thermometers in particular ways.

700. Exactly; at present you have neither the time nor the money to do it?—To do it satisfactorily in a reasonable time.

701. I mean that would be one of the objects of the physical laboratory to carry out such investigations?—Certainly.

702. It would help ultimately, but it cannot be charged to the public immediately, so to speak?—That is so.

703. (*Mr. Rücker.*) There is only one other question I wish to put. I think you are prepared to hand in a scale of charges at Kew?—Yes. (*Vide* Appendix.)

704. (*Sir John Wolfe Barry.*) With regard to thermometers, do you test the glass at all as a material?—No, we do not.

705. You only test the results from the glass as supplied?—That is so. At the present moment we are making some experiments for Messrs. Powell on the peculiarities of different kinds of glass—on the thermometric peculiarities, but not on the chemical ones.

706. You do not investigate the constituent parts of glass?—No, we do not, and we have no means of doing so.

707. Nor of any other material, I suppose?—No, we do no chemical work.

Mr. Shelford Bidwell, F.R.S., called; and Examined.

708. (*Mr. Rücker.*) I believe that you are President of the Physical Society?—Yes.

709. You have given considerable time and attention to scientific research?—In the way of private experiments, not in any institution.

710. You have not had any close connections with the trade applications of science?—No.

711. Have you formed from the point of view of the investigator any opinion as to the desirability of establishing a national physical laboratory?—Yes, especially in relation to tables of constants, the physical properties of metals, and so on.

712. How do you think they would be specially useful?—I have no knowledge on the subject except in the way of experiment. In the case of some experiments which I made a few years ago in relation to the Hall effect—I read a paper before the Royal Society on the subject—and another investigation on the Thomson effect, I had an idea that both those effects could be found to be connected with other properties of metals—specific resistance and expansion by heat and specific heat; but I found it quite impossible to obtain any data from any published tables upon which I could rely. The results of different authorities sometimes differ by as much as 20 per cent., often by as much as 10 per cent. For instance, the values of the co-efficients of expansion of silver and copper as given by good authorities differ by as much as 10 per cent., and those of tin by more than 20 per cent. Of course, if one could select values from all those different tables one could get at almost any result; they are not to be depended upon at all.

713. Then you think that the progress of scientific research is stopped by the uncertainty as to our knowledge of important physical constants?—Certainly, in my own case.

714. What is the objection to the individual worker himself determining those factors?—In the first place he has not the apparatus as a rule. It requires apparatus of a special kind, and an expensive kind; in fact, to get good results the apparatus should be of the best possible nature. And then, again, it takes a great deal of time; the work is tedious, and it is difficult to find it interesting unless there is some special object in view.

715. Is it the kind of work in which the higher scientific quality of originality is required?—I should say that the work is more of a routine nature.

716. And work, therefore, that could be undertaken by officials?—Yes.

717. Under adequate scientific control?—Yes.

718. Is there any institution at present anywhere that you know in which such work is regularly done either in this country or elsewhere?—There is the Charlottenburg place, and I believe there is one in Paris, and, of course, there is Kew here.

719. Then you would yourself have found it useful to have had some authoritative tables of this sort prepared in such an institution?—Yes, very useful.

720. Have you any other reason for desiring the establishment of a national physical laboratory?—I suppose there are commercial reasons about which I know nothing personally.

721. Is it the case that new and improved methods are sometimes devised for such measurements which the inventor cannot himself apply to very numerous cases?—Do you mean on account of the expense or of the time?

722. Both.—Of course, the time taken up in getting the value of properties of matter is very considerable.

723. And that would be a bar?—Yes.

724. You think that when the investigator has brought forward a method which is generally admitted to be an improvement that then it is not necessary that he himself should apply it to all possible cases, but you think it might be useful to others?—Certainly it would be wasting the time of a first-class scientific man very often to do so; I mean he could employ his time to much better advantage.

725. Have you any detailed information as to the working of the Observatory at Kew?—No.

726. Do you think that it is desirable that if such a national physical laboratory were established it should be in or out of a large town?—I should say it should be near a large town, but not in the town.

727. As far as you know, the site of Kew satisfies those conditions?—Yes, as far as I know.

728. What are the difficulties that are now arising with regard to physical investigation in a large town?—The difficulty is caused by the commercial use of electricity amongst other things, and, of course, the vibration caused by traffic is a serious drawback.

729. Both those?—Both those would be avoided at a place like Kew.

730. (*Sir Courtenay Boyle.*) May I ask what you mean by the determination of physical constants?—I mean such things as the specific resistance of a metal and the co-efficient of expansion, and the specific heat, and I believe that the recorded values of density are very untrustworthy in many cases.

731. Take a metal like steel—those are only three qualities, and there are many other qualities of steel which would have to be investigated, are there not?—Rather commercially than scientifically.

732. The electrical resistance, for instance, is a very important point?—Yes.

733. But that has nothing to do with expansion, has it; it is quite different?—One cannot tell; it might possibly be connected with expansion, but it does not seem likely.

734. But, still, as far as we know, it is a different phase of investigation?—Yes; but my point is that it is almost impossible to tell what value these determinations will have till they have been carried out.

735. I quite see your difficulties, but what I want to know is to what extent you would recommend the State to overcome them?—The probability is that they will be of immense value in unlooked for ways, and it is not the kind of work that would be undertaken by a scientific man without having some special object in view. All these things ought to be done systematically.

736. But directly a State Department was started it would be open to the applications of everybody, scientific or otherwise, who would wish his own particular investigation to be conducted there, would it not?—No; I think not. I think that the work of a National Laboratory ought to be confined to such things as I have mentioned—not undertaking miscellaneous scientific investigations.

737. The behaviour of steel under pressure and under hammering is a very important thing, is it not?—Yes.

738. That would have to be investigated?—That would be more the kind of work that would be done by commercial firms and engineers.

739. It is very important for the State to know how steel behaves, is it not?—Yes.

740. Apart from commerce it is very important indeed for scientific purposes, is it not?—I have no doubt it is.

741. Broadly speaking you would mean by the determination of physical constants, the behaviour of certain materials under a very large number of conceivable cir-

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cumstances?—No; not a very large number, perhaps eight or ten, at the most.

742. Well, eight or ten?—I should hardly call steel a scientific material in that sense. I think that that work ought to be done by the nation which is of such a character that it would not be undertaken for the sake of industrial purposes by private firms.

743. For scientific investigation rather than for industrial purposes; is that the line you draw?—I know nothing about industrial purposes—that is, speaking from my point of view.

744. You desire it for scientific investigation?—Yes; which of course may lead to commercial results of the highest importance; almost every industrial application of science has begun from that.

745. It would have to be a very elaborate laboratory, would it not, and very far-reaching to examine the behaviour of the various matters: glass, iron, steel, copper, silver, gold—rather a serious undertaking, would it not be, for the State?—It might be very big; but on the other hand a great deal might be done in a much smaller way.

746. (*Sir Andrew Noble.*) You are aware that lately there have been published by the Smithsonian Institute, I think, five or six volumes of physical constants?—Yes.

747. I suppose you would say that some have been determined with great accuracy, and some with little?—Yes.

748. But your view would probably be that some committee should have the power of directing what particular constants were to be examined?—Yes, a committee or a director—a single man.

749. Of course, as Sir Courtenay Boyle has said, it would be a very serious thing if everybody were at liberty to request that the innumerable physical constants that have been published should be re-examined?—Certainly; it should be left, in my opinion, entirely to the discretion of an expert director. He might, of course, weigh the opinions of scientific men on the subject.

750. If you leave it in the hands of one I fear from one's own experience that he would be very likely to have what he wanted himself done, and not what was of importance to the country and to other sciences?—Of course one would assume that the director of a laboratory of this kind is not commercially interested in anything else.

751. No, but he has his own prepossessions very frequently. I only want to draw out your opinion as to whether it would not be better if the direction were placed in the hands of, say, the Royal Society, or, say, of a committee of the Royal Society, to direct what should be done?—That is a matter of detail; I have not considered that point at all.

752. I suppose, taking the subject of metals, you would wish some such subject investigated in addition to those you have mentioned. I take, for instance, the secular variation of a metal like steel under considerable stress frequently?—Yes.

753. And the investigation would have to be one stretching over long periods?—I am not sure whether a national laboratory would be the right place for prolonged experiments of that kind.

754. Would you prefer that it should be done by a private individual?—Yes; by engineers.

755. Engineers have generally their own things to do?—It concerns engineers.

756. No doubt; but then what concerns engineers in such things also concerns the country?—Quite true.

757. (*Sir John Wolfe Barry.*) Do you attribute this large discrepancy between 10 per cent. and 20 per cent. in these matters to the want of means chiefly, or to the want of continuity of observations?—I should think both.

758. I suppose you would say that the continuity of observations on such matters as physical constants would be of the highest importance?—Yes. Another matter of great importance is the choice of the observer—the experimenter. It requires a man who is more or less of a specialist to obtain results that can be relied upon in a given department.

759. Then these discrepancies would be due to all those three causes?—Yes.

760. Which would be eliminated, in your opinion, at a national physical laboratory?—Yes.

761. I suppose the determination of those constants of metals might have the highest possible commercial importance?—I should say it is certain to; but one cannot foresee in what way until one has these data to work with.

762. Take such a case as the fatigue of metal under stress; we know that that is a matter of the highest importance to the travelling public, for example?—Yes.

763. I do not quite understand why you would say that a matter of that sort would not form a proper subject for investigation at a national physical laboratory?—It might; but when there is an immediate purpose to be served there are so many other people who are willing to undertake the investigation. The great object, so far as I can see, of a physical laboratory is that it will acquire knowledge, which is sure to turn out to be useful, but which no private individual or private firm will undertake to work for, because they cannot see any immediate results to be obtained from it.

764. Take the case of the fatigue of metals; do you think that private individuals would undertake a long continuity of experiments which would approach to the authority of the investigations of a national physical laboratory?—If in the opinion of the director of such a laboratory, or of the committee of direction, it is a proper subject, in that private individuals would not undertake it, then I suppose it ought to be investigated in the laboratory.

765. Therefore you would leave that in your opinion either to the director, or as Sir Andrew Noble suggests, to a committee?—Yes.

766. (*Mr. Roberts-Austen.*) Are you aware that the physical constants of metals and alloys are affected by very minute quantities of impurities?—Yes.

767. Do you think that the preparation of metals of standard purity would be a matter of great advantage and would constitute the first step towards the kind of investigations you contemplate?—Undoubtedly. No doubt many of the discrepancies that I have mentioned before are due to slight traces of impurity in the metals examined.

768. These are essentially questions that no private individual would conduct, because occupying too great a length of time without having sufficient personal bearing?—Exactly.

769. (*Mr. Chalmers.*) Do you attach importance to the testing and verification of instruments for physical investigation?—Yes; certainly.

770. On what lines particularly? With reference to commercial purposes, would you say?—I am not prepared to give any evidence at all about the commercial purposes, but for scientific investigation it would be of the greatest assistance if one could send one's measuring instruments to be tested by an authority that could be relied upon, instead of trusting entirely, as one often has to do, to one's instrument maker. Of course one does one's best with a new instrument to test it, but sometimes it is practically impossible to do it, and in any case it takes a great deal of time.

771. (*Mr. Siemens.*) Are we to understand that you would make this a purely scientific institution?—No, certainly not; but as to the other branch of it—the commercial branch of it—I am not prepared to give any evidence, because I know nothing about the subject.

772. I understand that; but you have been giving your evidence all the time as if it was only scientific men who should direct what was to be done, as if only scientific men were to do any work there, and as if you do not want them to undertake observations which give immediate results; so, therefore, it would appear that you want it to be entirely scientific?—I have been speaking from the point of view of a scientific investigator entirely, and I know nothing about the commercial part of it.

773. Therefore you do not want to say anything about the commercial side?—Just so; but I have no doubt it would be of very great advantage to the commercial world as well as to the scientific world.

774. (*Dr. Thorpe.*) What is your idea as to how the cost should be met?—I am afraid I cannot give any opinion upon that point. The cost of the verifying instruments and standardising instruments probably might be to a large extent met by charging moderate fees for testing; but as to the other part, the determination of the constants of materials, there could be no payment made for anything of that kind.

775. Supposing an investigator required, we will say, a series of observations to be made on the specific heat of pure metals?—That would be a very large order.

776. It is a very large order, but who is to bear the cost of that—the State entirely?—The State. Perhaps I may say that I consider that an extreme case which is not likely to be sanctioned by the Director.

777. (*Mr. Rücker.*) All proposals of this sort would have to be submitted to some authority, either the Director or the Committee, and a selection would be made?—That is exactly what I mean.

778. (*Dr. Thorpe.*) Take anything else you like which involves the compilation of exact data of numerical constants of this kind; they will all require a large initial expenditure in the preparation of pure material, and in

observations made over long periods of time, which mean, of course, considerable expenditure in the matter of salary?—Yes.

779. Is it your idea that all this should be borne by the State?—I should say that if the cost is not borne by the State such work is not likely to be done at all—at all events, not to be done systematically. I say that the present imperfect state of knowledge on the subject is most prejudicial to the advance of science, and, therefore, indirectly to the welfare of mankind.

780. (*Sir John Wolfe Barry.*) You said that in your own investigations you have a great difficulty in getting scientific instruments verified; have you used the Kew Observatory for that purpose?—No; but I have not had personal difficulty in getting things verified.

781. I thought you said you had to rely upon the manufacturer entirely?—Yes, but in my own work I have not had any cause to make accurate measurements with the instruments ordinarily supplied by manufacturers.

782. Then I a little misunderstood you?—I was talking about scientific men in general.

783. You mean not your own instruments, but those of scientific men in general?—Yes.

784. Do you think it is not known that Kew will verify scientific instruments?—Kew will verify a selection of things, such as thermometers.

785. Cannot you tell us exactly what is the difficulty which presses upon scientific men with regard to the Kew Observatory?—Well, if one buys an electrical condenser one takes one's instrument-maker's word that its capacity is, say, a third of a microfarad; it may be 10 per cent. wrong, but it would be very laborious indeed to test that in one's own laboratory, and there is no place where one can send it to be tested and certified.

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786. Dr. Chree, of Kew, told us that any individual might send instruments to Kew to be verified?—Such as standard resistances?

787. Subject only to the demands on the time of the staff at Kew; have you known of any refusals, or have you heard of any refusals?—I have never heard of any. Thermometers, chronometers, and some six or eight different kinds of instruments are tested at Kew.

788 I take your meaning to be that, giving all credit to Kew, there is a demand for much more than Kew can do?—Much more. When I said just now that I had not had any cause to make accurate measurements, I meant with such instruments as one could get tested. I have done a good deal with special instruments, which I have had to test myself as best I could at the sacrifice of a good deal of time, and I am not always sure, on account of not having proper facilities for testing, that my results are very accurate.

789. What I rather wanted to bring out is whether you have been refused at Kew to have these instruments verified?—No; I have never sent anything there.

790. (*Mr. Rücker.*) Your work has chiefly been done, I think, with instruments which have been fitted up by yourself?—Yes, or specially made instruments.

Mr. Richard Tetley Glazebrook, F.R.S., called; and Examined.

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791. (*Mr. Rücker.*) You have been for many years secretary of the Electrical Standards Committee of the British Association?—Yes.

792. In connection with that you have carried out standardising work at the Cavendish Laboratory?—Yes.

793. Could you mention the principal pieces of work that you have done in connection with that?—It commenced with the determination of the ohm in 1883-84 or thereabouts; then there was some work on the specific resistance of mercury, and then there was some work on the Clark cell as a standard of electro-motive force, which was done more or less for the Committee on Electrical Standards that was appointed by the Board of Trade. Then at the same time I had the planning of the ampère meter for the Board of Trade, in conjunction with Major Cardew and Mr. Horace Darwin, who actually made it; and the testing of the Board of Trade standards of resistance, which were made by Messrs. Elliott Brothers. Then I have constructed for the British Association Committee a standard air condenser, and have made comparisons of the standards of resistance and of electro-motive force which I have at Cambridge, belonging to the British Association, with those of France, Germany, and America. I am occupied somewhat frequently now in testing standards of electro-motive force, of capacity and of resistance, sent by makers in London and different parts of the country, and by workers elsewhere. The particulars of the work are contained chiefly in the reports of the British Association on Electrical Standards, and in these papers which I have here, which, if the Committee wish, I could leave, in case it is desired to refer to them.

794. If you will hand them in we shall be obliged to you. Is there any special interest attaching to the standards of resistance that you have at Cambridge?—The standards of resistance at Cambridge are the original standards of the British Association which were made many years ago—1866-70—under Professor Clerk-Maxwell and others. The fact that they are so old renders them of very considerable importance, because we are more certain about their history and the secular changes that take place with time.

795. Did the work you did in connection with the Board of Trade standards depend on those?—The Board of Trade standards depend on them, and they have been compared from time to time with the mercury standards.

796. Do you think that the standardising work you do at present could be increased largely if you were to desire it?—If I were to desire it, it could be increased very considerably. I limit the resistance standards which I test to standards which are powers of 10—1 ohm, 10 ohms, 100 ohms, etc., or tenths of ohms; I decline quite rigidly to attempt to test any others. During this present term I have had three of four letters that I should like to refer to, as they would explain the point. One from Messrs. Elliott gave me particulars as to a special form of resistance box, which was to be used in some experiments that were going to be performed, and they said that if I would test that carefully, it would add to the value of the box and to the accuracy of the work. Another letter which I have here is from Lieutenant Hetherington, who is, I think, Inspector of the Royal Engineers' Stores at the Royal Dockyard, Woolwich. It is dated November 4: "Sir,—I wish to send you a standard condenser, one micro-farad capacity, for verification. I shall be glad to know the charge for such verification. The condenser is made in four sections—a tenth, a third, and a half micro-farad." Another is a letter from Professor Ayrton, which came to me on November 7: "You have probably seen a note in the electrical papers which has just appeared regarding the permanency of the four resistance coils which you were so kind as to test for Jones in 1894"—that is, Professor Viriamu Jones.—"We should esteem it a great favour if you could kindly let us have the present value of the four coils at a temperature of about 15deg. C., that is at the temperature of your 1894 tests. Would it be possible for you to find time for this if I had the coils sent to you to Cambridge? Jones's determination of the ohm in 1894, using your values for the resistances, and Nalder's values for the temperature-coefficients of these four coils, led him to think that the international ohm equalled about 0·99983 true ohms; whereas the results of our joint work in London on the McGill Lorenz apparatus led to the Board of Trade ohm (as transmitted to us by the tests of these four coils made at the Board of Trade in August of this year) being equal to about 1·00025 true ohms"—a difference of four parts in 10,000 or thereabouts. "This latter is independent of possible variations of temperature coefficients." Then I have been in correspondence for some time past with Messrs. Nalder Brothers as to the variation of resistance with the temperature in certain standard coils—some standards that I have at Cambridge and some standards of their own—which has involved a good deal of work. I have been obliged to reply to these three or four letters that I have just read, that at present—at any rate, until the vacation comes—it is quite impossible for me to undertake additional work. My work is teaching work in Cambridge, and any testing work of this kind—and this is somewhat elaborate—can only be done in vacation time, or when my lecturing work happens to be particularly light. I have another letter that bears upon the same point which comes from the Indiarubber and Gutta Percha Telegraph Works (Limited), at Silvertown. The manager of the Electric Department told me some little time ago that they were in the habit of sending their standards regularly to Germany to standardise, and he writes: "There is no objection to your mentioning that I have had the standard resistance coils of our instrument department tested at the Reichsanstalt for the last three years. My reason for having this done was purely a consideration of expense." That leads me to say that one of the ways in which I have kept the work small at Cambridge has been by charging, with the permission of the British Association Committee, a consider-

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able fee for the work—for instance, a guinea for each coil of one ohm, £1 10s. 6d. for coils of 10 ohms, or 100 ohms, and so on for the others. That has been done purposely to limit the work. I am quite clear that I could do a very large amount of more work than I have done for some time past if I wished.

797. Is the work thus done by you, work which is at all covered by the establishment of the Board of Trade Laboratory?—A good deal of the work that I do I think could be done at the Board of Trade Laboratory.

798. Do you know at all why you are applied to?—No, I do not know of any reason specially.

799. Are any of those things that you are asked to undertake things not done at the Board of Trade Laboratory—for instance, with regard to the measurement of capacity?—My impression is that they have no standards of capacity at the Board of Trade Laboratory, but I am not positively certain of that.

800. What are the reasons, apart from your own personal convenience, which lead you to desire that there should not be a large increase of this work in Cambridge?—I should say that I am Assistant-Director of the Cavendish Laboratory at Cambridge, and, of course, my position there is a university official position—a teaching position—the University supplies the room, the gas, the water, and the various other small matters in the laboratory. There is a very strong feeling in the University against commercial work being done in the University teaching and research laboratories. It is necessary to keep the amount of such work as small as possible. I have been treated with every consideration in this matter, and my superiors there have been most kind in allowing me to do the work, in arranging a room for me, and so on; still, I do think that a large amount of commercial work could not be done there, and ought not to be done there.

801. It is not work of a kind that you think a university ought to undertake?—It is not work that a university ought to undertake.

802. (*Mr. Chalmers.*) But with the exception of the measurement of capacity, do you think that the Board of Trade might take up that work, or would be able to take it up?—The Board of Trade would be able to take up, I think, the actual testing of the coils. I do not know the details enough, perhaps, to say whether they would be able, with their present arrangements, to take up the other points that have been mentioned here—I mean whether they are prepared, for example, to investigate why those results of Professor Ayrton's now differ by 4 parts in 10,000 from the results that Professor Jones got three or four years ago, or whether they are able to take up the question as to whether the temperature-coefficients of certain important standard coils have changed appreciably in the last five or ten years. I have not really the means of knowing.

803. That would be simply the scientific aspect of the thing apart from any commercial use of it?—I think not exactly the extremely scientific aspect of the thing, because unless these points are attended to the standards cease to be useful for purely commercial purposes. May I say with regard to that that two at any rate of the letters I have read have come from commercial firms.

804. (*Dr. Thorpe.*) At the same time they are firms of such standing that they would be well aware of the Board of Trade Laboratory?—Yes, certainly.

805. There would be no obvious reason why they should not apply to the Board of Trade Laboratory?—I do not know why they should not apply to it.

806. (*Mr. Rücker.*) May we take it that the number of applications you have had during the last few weeks in the present term is a fair sample of the number of applications you have had in a similar time at other periods of the year?—Yes, I think so.

807. Have you given any attention to the question of the establishment of a National Physical Laboratory?—I have been much interested in that for the past two or three years.

808. Have you formed any opinion as to the kind of work which you think should be done there?—I have made some notes as to what electrical testing work I think wants to be done, and which it is important, I think, for commercial purposes should be done. The notes include points that I have already referred to. With regard to resistance coils, Professor Ayrton's work shows a change of 4 parts in 10,000 in certain coils, and it is important to discover where this discrepancy lies. The Board of Trade certificates at present, I believe, only go to 1 part in 1,000, and I do not think for commercial purposes it is necessary that they should go further. But if an error or a change of 4 parts in 10,000 has crept in in three or four years, unless we know where the source of the error is, it is clear that quite shortly it will come within the limits of error, which are assigned to the certificates issued by the Board of Trade itself; and if there is any doubt of 4 parts in 10,000 in standard coils, it is clear that certificates to a somewhat less degree of accuracy will not be accepted by commercial people outside as satisfactory. For coils of ·01 ohm resistance, which I am informed are now used for commercial purposes, an error of ·0004 ohm would be most important. Then there is also this question of the temperature co-efficients of some of the standard coils. At present I do not think the uncertainty in temperature co-efficients, which Messrs. Nalder have called my attention to, will produce an effect of 1 part in 1,000, unless the temperature at which the measurements are made is very far from that ordinarily used, but it will produce an error of 4 or 5 parts in 10,000, or that kind of figure. Here, again, so far as we know, there is a growing change, or a growing error, that requires to be investigated if the Board of Trade standards are to have the weight that we should wish to see attach to them.

809. These errors might conceivably be additive?—They might certainly. Arrangements again are needed, I think, whereby the standards can be readily compared with mercury, or by which their value can be determined absolutely. Might I refer to one of the sentences in the Board of Trade Committee's Report? Resolution 5 of the Resolutions of the Committee which were signed on November 22, 1892, is to this effect:—"That a material standard constructed in solid metal should be adopted as the standard ohm, and should from time to time be verified by comparison with a column of mercury of known dimensions." I think it was then realised that that would be a work of immense importance. I know that it is done regularly and systematically at the Reichsanstalt, and that the value that is attached to the German certificates depends to a large extent on that fact. I have never been informed that there are any means of doing that at the Board of Trade Laboratory at present, and I do not think it has ever been done, but I do not know positively about it.

810. You were one of the Committee, I think, who were entrusted with the work of starting the Board of Trade Laboratory?—Certainly.

811. So that at all events when it left the hands of the Committee you can say no such arrangements were made?—No arrangements had been made at that time for doing that.

812. You think, nevertheless, that that is an essential, or at any rate a very desirable part of the work of the institution?—I think it is an essential part of the work of the institution that the standards should be compared in that way.

813. (*Mr. Chalmers.*) How often would you suggest that that kind of comparison should be made?—Twice a year perhaps.

814. Is the comparison a long business?—It requires some days' careful work.

[*Addendum.*—The answers to this and the preceding question refer solely to the comparison of coils with mercury standards already set up. The construction and verification of the mercury standards may take months.]

815. (*Mr. Rücker.*) Is the apparatus required elaborate?—It is not very elaborate, but the means of working to a considerable accuracy must exist.

816. Have any difficulties been found lately in fitting up the apparatus for measurement with the mercury column?—It is a difficult problem, unless you have some experience and practice; there are difficulties in fitting up the apparatus and working it.

817. It is expert work?—It is expert work.

818. (*Dr. Thorpe.*) Would the position of the Board of Trade Laboratory be in any way detrimental to such comparisons—I refer to its contiguity to traffic and lines of traffic?—I should doubt if it were possible to make them satisfactorily there.

819. (*Mr. Rücker.*) Would the neighbourhood of an electric railway seriously add to that difficulty?—Very seriously no doubt.

820. Powers are, I think, already taken to have the underground railway which lies near the Board of Trade Laboratory run by electricity; do you think that would seriously interfere with their work—but perhaps you hardly know the distance sufficiently well to answer this question?—I do not know the distances sufficiently to say positively, but, speaking generally, I can say that the near contiguity of an electric railway would make the work extremely difficult.

821. With regard to the standard of current, have you anything you want to say about that?—There is considerable uncertainty as to the exact value of the electro-

chemical equivalent of silver. So long as the same value is accepted everywhere—and that was arranged for at Edinburgh before this Report was issued—the uncertainty does not matter; but the question of making a change is now being mooted. There was a paper published in the early part of last year from the Reichsanstalt, and I understand there are experiments going on in France on the question, and it is quite possible that there are American experiments also; so that Continental nations and America may make some change in that value. If that were done, and no corresponding change were made in England, it would at once introduce discrepancy between our commercial standardised instruments and those used abroad, and would probably lead to our instruments being entirely disused abroad. Of course, we could follow suit—we could accept the results of the Reichsanstalt or of the American Laboratories if we liked, and change our own standards, but that does not seem to me a satisfactory way of doing it; the work of the Reichsanstalt, which would seem to lead to a different value, ought to be checked and verified in this country before we suggest any modification in our English standards.

822. Is that again a difficult and a lengthy piece of work?—That is a difficult and a lengthy piece of work. The British Association Electrical Standards Committee, I think, at their meeting this year at Toronto undertook that work—at any rate the best manner of carrying it out is now being discussed. The same kind of remarks, I think, apply to the standard of electro-motive force. Improvements and modifications have been made in the Clark cell, which is the adopted standard of electro-motive force and by far the best; but we do not know for certain now that the form which was adopted in England is the best form, nor that the specification for drawing it up which was approved in 1892 is now exactly the best.

823. (*Sir Andrew Noble.*) May I ask if that is Lord Rayleigh's form—the H form?—The form in 1892 was not the H form; I think probably the H form now is better. Then there is the question of the standard of capacity which has been already mentioned; a recognised standard there is, I think, wanted. There are some air condensers at Cambridge which were made under my directions, and those are recognised in a good many places; but those are the only recognised standards of capacity existing. Dr. Muirhead has some similar ones; he also constructed his for the British Association Committee, and he and I compare ours together from time to time.

824. (*Mr. Rücker.*) Have you done any work in comparing English standards with those of other countries?—I have had standards sent to me for comparison from France, Germany, America, and Russia. Before the British Association meeting at Edinburgh (at which there was a conference between representatives of England, France, Germany, and America for the purpose of discussing this question of electrical standardising, which really led to the formulation of the resolutions of the Board of Trade Committee and of their adoption elsewhere), Professor Carhart, of America, and some representatives of Professor Helmholtz, of Germany, came to Cambridge for some little time, and tested and compared their apparatus with my own there. I think work of that kind has been done since to some extent at the Board of Trade Laboratory, but it is work that ought to be systematically and continually done.

825. And you think that ought to be done at the public cost?—I think it ought to be done at the public cost.

826. I suppose your comparisons would have no official value beyond that given by your position as secretary of the British Association Committee?—None whatever, I think.

827. (*Dr. Thorpe.*) Do you actually issue certificates, or in what form do the results of your comparisons go out?—I issue a certificate. I am sorry I have not brought a copy with me, but it is roughly to the effect that resistance coil No. so-and-so has been tested by the Electrical Standards Committee of the British Association, and its value has been found to be so-and-so at such-and-such a temperature, signed by myself as Secretary of the Standards Committee. I can easily send up a copy of the certificate if it is desired.

828. Then in one sense that certificate would have about the same value as a certificate issued under the auspices of the Kew Committee?—I suppose it would. I suppose the Kew Committee bears to Kew Observatory pretty much the relation that my Electrical Standards Committee bears to my work at Cambridge.

829. (*Mr. Rücker.*) Is this whole work of determining electrical standards and electrical testing in a progressive state at present?—Very distinctly so. There are questions continually arising as to whether the methods of electrical testing at present in use are the best methods to use. For instance, Mr. Griffiths has lately suggested various ingenious devices for making comparisons more readily and more easily. Those devices, if they are successful, ought to be introduced into any national standardising department, but there ought also to be some department which could test and check the devices before they were formally introduced into the actual standardising work or standardising laboratory, so as to ascertain that they were really improvements on the methods that were in use in that laboratory previously.

830. Although you are partly responsible for the installation at the Board of Trade Laboratory, you do not regard that as a final arrangement?—Not in its existing form.

831. You think it is desirable that changes should be made as science progresses?—I think it is most desirable that changes should be made as science progresses, and that these changes should take place under the direction of scientific men.

832. As to the various changes and corrections of which we are now speaking, do you think that they are matters of only high scientific importance, or will they have more commercial value?—I think that all of them may in time have considerable commercial value; the sources of error that I have been mentioning are all progressive.

833. This testing of new methods ought, as you think, to go on continually in some institution?—Yes.

834. (*Mr. Chalmers.*) I did not quite catch the end of your sentence in a previous answer. You said these new methods should be introduced under the direction of someone—was it an individual, or a body, or the Royal Society which you had in mind?—I think a committee would be of very great assistance, provided of course the staff of the department was sufficiently large and sufficiently competent to carry the work out.

835. What I wanted to get at was whether you would regard an ordinary Government laboratory as being an executive place which should be kept in touch through a committee with the world of science; would that be your view?—I do not think that alone would be sufficient, because I do not think the work that I have just been describing is exactly executive work.

836. (*Dr. Thorpe.*) You mean it is rather more of the nature of investigation?—It tends to become somewhat of the nature of investigation.

837. (*Sir Andrew Noble.*) I was going to ask very nearly the same question. I understand you to think that an expert committee, or a committee somewhat analogous to the visiting committee at Greenwich, would be necessary or desirable before handing any alterations or improvements in standardising over to an establishment like the laboratory of the Board of Trade, who may be considered more as an executive body?—That was my meaning in part, but I think rather more than that. I think that there should be somebody or some persons responsible for testing and checking those methods before they are handed over to the executive body.

838. That is what I mean—that some body of experts in the particular line should decide upon the desirability or otherwise of introducing the new matter proposed into the national standards?—Yes, that I should agree to entirely. I am not quite certain that I have made the whole point clear; I did not mean that this body of experts were to be expected, as it were, to decide on casual questions submitted to them, unless they also had some means for having those questions properly investigated.

839. Which could be done at a national physical laboratory?—Yes.

840. (*Mr. Rücker.*) Have you yourself done any work in testing apparatus for domestic purposes or trade purposes other than the electrical work which you have mentioned?—No; not any beyond the electrical work. I think it ought however to be remembered that there is a considerable amount of testing for trade purposes that needs a higher accuracy than the ordinary tests which you would apply for certificates that you would issue for instruments used commercially; I mean to say that a maker of instruments must have his own instruments tested to a higher degree of accuracy than the instruments that he issues for purely commercial purposes.

841. That is a trade demand for higher accuracy than is got at the Board of Trade?—A trade demand for higher accuracy than is required for the certificates of the Board of Trade.

842. You have told us that work of this sort is being done in Berlin and elsewhere. I should like to know whether you think that the ultimate value of these certificates depends not upon whether they reach a standard just fitted for trade, but whether they have a high scientific value also?—I think the fact that one feels sure that the certificates of the Reichsanstalt have a high scientific

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value, in addition to the fact that they are suitable for trade, adds very considerably to the respect which they meet with everywhere.

843. And thereby the German manufacturer benefits?—Certainly.

844. (*Mr. Chalmers.*) You are speaking with regard to electrical apparatus?—I am; I do not know very much about the others.

845. (*Mr. Rücker.*) The same would hold with regard to thermometry for instance?—Yes; I know enough to say that. Then I am extremely interested in optics and optical work, and I think certainly that the same holds with regard to investigations on the use of glass for optical work that have gone on at the Reichsanstalt and at Jena.

846. (*Sir Andrew Noble.*) I have only to ask two questions—in ignorance; with reference to Professor Ayrton's determination of the apparent change in resistance, was that made by comparison with a mercury column of a given section and a given length?—No; it was made by an absolute determination by the Lorenz method—the original method whereby Lord Rayleigh determined the value of the ohm.

847. You have referred to another question, namely, the uncertainty as to certain electro-chemical values of silver; is that due to a want of purity in the metal—because silver should not be difficult to get pure, should it?—It is due to an uncertainty as to the exact conditions under which the silver is best deposited from the silver nitrate solution; it depends on the amount of oxygen present, for one thing.

848. Which is absorbed when it is fused?—Not exactly.

849. (*Dr. Thorpe.*) Which it occludes in the deposition rather?—Yes, probably, but the action is at present uncertain.

850. (*Mr. Roberts-Austen.*) I have just heard of the failure in the tropics of a large number of coils of platinoid and of German silver, the question having been submitted to me. Is not the question of the molecular changes in alloys one of very great importance which ought to be settled by some such body as is contemplated?—That I think is very intimately connected with these changes which appear—through Professor Ayrton's recent experiments to which we have just been referring—to have gone on in certain coils that have been in England in the last four or five years.

851. This is a question of a whole series of coils, both in platinoid and in German silver, all of which have gone wrong?—It is possibly partly due to an acid impurity in the paraffin in which they are embedded; that is a serious source of error and has spoiled a large number of coils.

852. I take it that the whole question of the molecular arrangement of alloys is one of the greatest importance?—Yes.

853. Of commercial importance as well as of scientific importance?—Certainly.

854. (*Dr. Thorpe.*) I take it that you are fairly conversant with the installation at the Board of Trade?—I have not seen much of it since it was originally put up.

855. When did you last see it?—Probably some time in 1895, but I am not quite sure.

856. Have you reason to know that there have been any extensive changes since 1895?—I do not know of any.

857. Could you favour the Committee with your opinion as to the general suitability of the installation at the Board of Trade to undertake any immediate, or immediately prospective, demands upon it?—I should have thought that the Board of Trade Laboratory might undertake the demands for testing to a trade degree of accuracy, one-tenth per cent. or so, but that it is extremely doubtful if it is in a position at present to undertake the kind of testing that I have been describing, or the work that it appears to me most necessary to do in order to trace and keep a record of the changes that go on in the standards.

858. For example, if an instrument-maker desired to have a standard in his own possession by which he could compare his instruments before he sent them out, do you think the installation at the Board of Trade would be sufficient for him to go to in the first instance for the creation of his own standard—perhaps I have not made myself clear?—I think I understand you, but I am not sure that I have sufficient knowledge of the exact condition of the installation at the present moment to answer. It would not have been sufficient when I was there in 1894 or 1895—I am not quite sure which—but it may have been added to considerably since then.

859. I gather from your evidence that a considerable number of persons, who must be conversant with matters as they are carried on at the Board of Trade, continue to come to you for information as to standardising their instruments?—Certainly.

860. Therefore they do not go to the Board of Trade to get these standards which they want for their own requirements?—I do not think they do.

861. Do you know of any reason why they should not?—I presume it is that they prefer my certificates to the certificates that they get from the Board of Trade. I should, perhaps, say with regard to that point that I think I have advantages at Cambridge that are not possessed there. I can only obtain results to the high degree of accuracy that is often wanted by working at night, or by working in the vacation time when there is no one in the laboratory. I doubt if it is possible for the Board of Trade in the present position of their laboratory to do the kind of work that I have to do, or to do anything more than the issue of certificates to about one-tenth per cent.

862. May I gather—if I may put it so—that the trade value of a certificate, issued under the auspices of the British Association Committee, is higher than that issued by the Board of Trade?—It would appear that that is the case, since they come to me for certificates.

Professor Oliver Lodge D.Sc., F.R.S.

Professor OLIVER LODGE, D.Sc., F.R.S., called; and Examined.

863. (*Mr. Rücker.*) I think you have been long interested in the question of the establishment of a national physical laboratory?—Yes, I have.

864. You drew attention to the question some years ago?—I drew attention to the question in 1891, I think. I had an opportunity of doing so at the British Association meeting at Cardiff.

865. Can you give us shortly the principal reasons why you think it is desirable that such an institution should be established?—Because it seems to me that there is a great deal in physics which an individual cannot do. First there are laborious series of precise quantitative determinations, especially those which are or *may* be useful in practice. It seems to me that there are methods invented by individuals which they apply to one or two substances and then drop, because they, quite properly, go on to other things. I think that it is only fair in that case that they should be taken up by a national institute, and pursued into the application to a great number of different substances. Then some investigations are too laborious for an individual, and they can be much better done by an official staff. Further, a national institution would be perennial, and could carry on continuity of investigation and researches that require a long time. It would also be the custodian of standards of measurement of all kinds, in a state fit for use and ready comparison. In fact, the reasons for establishing a national laboratory in physics are much the same as those that apply to a national observatory for exact and systematic measurements and observations in astronomy.

866. Do you think that any such institution should take up any special work with regard to the testing and verification of instruments?—Yes, I do. I think that would certainly be a part of its work.

867. And an important part?—An important part. I understand that in the Arts we are getting behindhand, and we shall get behind in the manufacture of exact work of various kinds, because we have no such institution for accurate standards. As you yourself know, we have often to go abroad, and are especially dependent on Berlin or Paris.

868. Would the researches carried on in such an institution be useful from the point of view of improving the verification and standardising of the instruments?—I think they would be essential to real standardising. It would be essential also to investigate the properties of materials, in order to know what is the best material for making these standards of.

869. Would such work interfere with the research work of individuals?—I should certainly hope not; I think not. It would be under the government of a Council of Advice, I suppose, and they would take scrupulous care to see that no interference with work that is being properly done by individuals should be attempted. It sometimes happens that an individual has done work

which might have been done in such a laboratory; Lord Rayleigh has several times done work of that kind, and so long as he is doing it, it could not possibly be better done. But that is rather an exceptional case; and, as a rule, such work would be more easily and readily done in a national institution.

870. Then you regard the research work, which ought to be undertaken there, as work of a special kind?—Yes; not pioneering work or qualitative work. I have divided physics into a certain number of heads, namely (1) pioneer work, (2) verification work (testing the conclusions of theory), (3) systematic measurements and examination of the properties of substances under all conditions. I regard the last as, perhaps, the most important from the point of view of the business which such an institution might undertake. Then the next head is (4) the precise determination of fundamental constants; I think that should be undertaken occasionally when wanted by the Arts; just as now, for instance, electrical engineers require a re-determination of the ampère. That would very properly be done there, even though it can be done by private individuals. Then (5) there is observational work; such work as was done by the British Association Committee on underground temperatures, for instance, might very properly be carried out in conjunction with such an institution, and the instruments could be tested there for surveys or expeditions. When an expedition is fitted out, I suppose the instruments are supplied and tested beforehand, as far as the astronomy is concerned, at Greenwich. We have no such place for testing things in general physics. Kew, of course, is the nearest approach to such a place. Then (6) there is constructional work; such work as the construction of Rowland gratings, for instance, or other precise operations requiring more than ordinary handicraft skill. We depend for them at present on America—on what is being done at Baltimore—but that cannot go on for ever. There are some things that the world might very easily forget how to do—the making of the finest optical glass, for instance, is a thing that is handed down as a trade secret; and other *präcisions-technik* are just the kind of things that ought to be taken up and understood in such a place as this, so that they shall not be lost. Then, further (7) there is the designing of new and more perfect measuring instruments—for instance, for magnetic surveys and things like that. It has been customary to use the Kew instruments, but it might be possible to devise better instruments as time goes on; and so in other cases of that sort. Then (8) there is standardising and other metrical work, including the calibrating of instruments sent in, and the issuing of authoritative standards.

871. I should like to draw your attention to the Terms of Reference to the Committee; the three things we are to report upon are "the desirability of establishing a National Physical Laboratory (1) for the testing and verification of instruments for physical investigation; (2) for the construction and preservation of standards of measurement; and (3) for the systematic determination of physical constants and numerical data useful for scientific and industrial purposes." With regard to verification work or examining results predicted by theory, do you think that comes under any of those heads?—I do not think it comes very clearly under either of those heads.

872. (*Mr. Siemens.*) Not under the words "numerical data"?—I was just going to say, under the third if any; it would come under "numerical data" in some cases. I was being asked whether it was important for practical purposes to examine the results of theories; I think it is. Suppose Ohm's law, for instance, had turned out to be false, as we know it has not turned out—it would be important to ascertain that, and I think the accurate testing of Ohm's law might properly fall under such an institution; that is an example of testing the result of theory in a certain case. That is a thing which is constantly wanted by electrical engineers, namely, the testing of a theory which may be true, but which may not be true. The same with Faraday's laws of electrolysis, for instance, at one time; and other results of theory where the theory has not been perfectly examined experimentally, the examination indeed being rather difficult.

873. You mean that when the data to be obtained were important, it should be done?—Yes.

874. Several of the other points you have mentioned obviously come under one or the other of those heads: but I should like to know how far you think observational work comes under them?—I do not think it does.

875. Or constructional work of the kind you describe?—Yes, there is the construction and preservation of standards of measurement. Very often a standard of measurement is not a thing that can be shut up in a box; it is really an instrument. I think in that case constructional work would have to come in, though it would not be a large part of the work.

876. From the point of view of improving the standards?—Yes. It would not be constructional in the sense of turning out a great number of instruments; it would only be constructional work of a very high class, producing a type of instrument for the information of the instrument maker.

877. You would not propose that such an institution should make and sell Rowland gratings, for instance?—I think that would depend rather upon whether a firm could be instructed to do it. I do not know whether it is a possible thing to enter into commerce. If it cannot be done commercially, it ought to be done somewhere, probably in such an institution, I should think.

878. (*Sir Andrew Noble.*) It would only be wanted for physicists?—And for chemists, of course. It is the most perfect form of spectroscope at present known. I believe spectroscopes are used in the Arts, though not such elaborate spectroscopes at present.

879. (*Mr. Rücker.*) Have you formed any opinion as to how such an institution should be governed?—I think we may learn something from what has been done in the Reichsanstalt; for instance, if we could only get a head of sufficient eminence, with a staff under him, and subject to a council of advice, something after the way that Kew is governed—that seems the method. I have not formed any better opinion than that.

880. Do you think that work of the kind you are describing could be conveniently undertaken in university laboratories?—Not frequently, or very much.

881. What are your reasons for that?—I feel that university laboratories are partly incommoded by students, and partly the man who has charge of them has to do a great deal of teaching, which cuts up his time, and partly because he is liable to migration, and does not remain very long in a single place except under very special circumstances. So that I do not think anything like continuity of investigation can usually be obtained. It seems to me that a university laboratory is well adapted for pioneering work, for qualitative work, and for rough quantitative work, which is of a very valuable kind—that is, finding out what sort of magnitude new quantities have. As Lord Rayleigh has said, if you do not know whether a thing is 6 or 6,000,000 it is a good thing to know that it lies between 600 and 700. That sort of measurement, the there or thereabouts sort of measurement, of new quantities that have never been measured before, can often be done in university laboratories. Occasionally it happens that a man in a university position makes a hobby of some accurate determination, and then, of course, results are often extremely good; and that I hope would never be interfered with; but I do not think that we should any longer leave it to chance to do these investigations that are so much wanted, if we are to take our proper place.

882. Have many such investigations been carried out in this country by wealthy amateurs?—Yes; I think the best of the experimental physics in this country has been done by wealthy amateurs.

883. Do you think that is likely to continue, or do you think it is becoming more difficult for the standard of precision required to be reached by the amateur?—I cannot say. If you can get an amateur like Lord Rayleigh to weigh hydrogen and so on, certainly you can do no better.

884. That is an accident—there you have got the right man?—Yes; and we may be a long time before we get work of that kind again going on. It seems to me that work of that kind is a lesson for the National Laboratory; the staff of the laboratory would learn from that how to do such researches. You would have that sort of individual work going on every now and then, say one in about fifty years, and that would give a fresh stimulus of instruction to the laboratory. In the laboratory, work of a lower kind, though first-class in a way, would be going on continually by the official staff. It does not require any genius, I suppose, to take a transit observation to six places of decimals now; but at one time it required great genius to make such a thing possible; now it can be done by a highly trained and skilled observer merely; it does not require to be done by one of any eminence.

885. You have served, I think, on the Government Grant Committee of the Royal Society?—Yes; I have.

886. You are acquainted with the work of that committee?—Yes.

887. And of the kind of applications that are made to it?—Yes.

888. In your opinion is the sum so granted by Government required for the calls which at present exist upon it?—Yes; the calls are always considerably in excess of

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the sum. That sum seems to me a very small sum for this nation to expend on science.

889. Then you do not think that there is any available balance which could be devoted to the purposes of a National Physical Laboratory?—No; indeed not.

890. (*Sir Andrew Noble.*) You mentioned standardising and other metrical work; that may mean a great deal, or it may mean comparatively little. I would like some kind of definition of what in your view it is?—I should take a wide view of that. I do not know whether in answering the questions it would not have been better to have read what I have written, because there I have thought it out rather more carefully. I say under this head: "Standardising and other metrical work, for ensuring precise intelligibility hereafter of all careful measurements now made, for issuing instruments comparable with each other, and for calibrating them by the absolute standards." I think in order to carry that out properly, a great deal of metrical work would have to be gone through, because fresh quantities constantly have to be standardised, and the standards have to be incorporated either in suitable substances or in definite measuring instruments. There is an illustration of the advantages of researches into the properties of materials for the purpose of standards which occurred last year—I do not know whether you have had that instance brought before you. M. Guillaume, in the French National Laboratory, in examining all the properties of nickel and steel alloys, found one which did not expand at all under the influence of heat. That came out of a research not for any particular purpose, but generally for investigating all the properties of these alloys. That particular property of not expanding under the influence of heat, if it had been known at the time of the Ordnance Survey, would have saved them a great deal of trouble in their measurement of the base line; it is evidently the metal to use for measuring standards, for all measuring rods, indeed, and also for pendulums. I apprehend that when it is applied to the pendulums of clocks it will be a decided improvement.

891. And so far of great commercial and industrial value?—Certainly; I should think so.

892. We are behind the Americans very considerably in the production of accurately-divided scales at very moderate prices, I believe?—I could not say.

893. You can get nothing in this country to compare with them, even in the case of small micrometers which you can conveniently carry in your pocket when you are making a number of readings to a thousandth of an inch, or of a similar value in a meter?—I know that some of the Americans are very much awake to the need of having such an institution on their side of the Atlantic; indeed, I have brought with me a paper by Mr. Webster, who is a physicist in America, and I might leave it as part of my evidence.

894. Your evidence then would be—I am now talking simply of industrial and engineering points—that what you have been mentioning would be exceedingly valuable to engineers?—Yes. I might take another instance, namely, with regard to electric conductivity. It might have happened that a perfect conductor was an impossibility in nature, but it turns out from the researches of Dewar and Fleming that at near absolute zero several substances begin to be almost perfect conductors. Now, if by any means it could be discovered how to fix them in that condition, or how to combine substances in such a way that they should be in the condition of anything like perfect conductors of electricity, that would be an extremely practical discovery and would almost revolutionise electrical engineering, because it would enable power to be conveyed to a distance without dissipation on the way.

895. (*Mr. Chalmers.*) Is there not a great temptation, therefore, to get a man to research with a view to discovering that, apart from any central institution?—I think there is, but I think it would be extremely difficult to do it; it would be like searching for a needle in a bottle of hay if you went looking for a thing like that by itself. I think that the way it will come will be by a comprehensive examination of the properties of materials under all conditions. At present the properties of solids are very little known to us, the properties of liquids and gases are much better known. The solids form an almost unknown region, and there is a fearful amount of work to be done in the examination of solids, because we have to investigate them under all conditions of pressure and temperature, and almost also of past history. But if this were done on a scale that has never yet been attempted, then I think we should find that a sort of order prevailed, and that things would fall into line; we should begin to see the way things acted, and we should be able to predict; we should find clues to fresh properties, and we should not then be searching for them in the dark; we should be able to find a great number of properties which now we have no knowledge of how to proceed to look for even.

896. (*Mr. Roberts-Austen.*) Take this particular case of Guillaume's alloys, the range of non-expansibility is a very narrow one, limited, if I remember aright, to 34 per cent. of nickel in the alloy; and it is essentially one, is it not, which would not have been found except as the result of a prolonged investigation?—So it struck me. That would answer the question that I was asked before—if anybody had gone looking for that solely, would he succeed? Everybody must have been looking for such an alloy ever since such a thing as a pendulum was invented. The expansion of things has constantly been a nuisance, but no one previously had been able to find the alloy; and it was found, not when it was being looked for, but in the course of a systematic research on certain definite metallurgical properties. Some researches which you conducted yourself on certain alloys discovered some remarkable properties which would never have been predicted, and would hardly have been understood, because they seemed exceptional.

897. In this particular case a variation of 10 per cent. practically makes a totally different metal of the nickel?—Yes; if I am right, another proportion gives an extremely expansive metal.

898. (*Mr. Chalmers.*) Do I understand you to advocate this laboratory with reference mainly to science?—I am mostly interested in science, certainly.

899. On that account you would naturally and necessarily be an advocate of it; but would you advocate it on other grounds than those of science?—Do you mean with reference to engineering applications?

900. "Engineering applications" expresses very much what I mean?—Yes, I think certainly it is wanted for those; indeed, I think that practical men are feeling the need for some such institution, and the Government having started a standardising laboratory at the Board of Trade has shown that something of the kind was wanted; though that is not of an advancing character, whereas what I advocate has something more to do with advancing work in new directions than with stereotyping existing practice.

901. As a part almost of a national movement to endow—I will not say to endow, but to take in hand—the advancement of science; that is, in the main, your ground, is it not?—Yes, it is. May I say here that the national recognition of physics, both pure and applied, is rather behindhand at present. We have a Government institution in so many other subjects; we have it in astronomy, we have it in geology (the Geological Survey), we have it in the Metallurgical Laboratories of the Mint and elsewhere; then we have it in the Natural History Department of the British Museum, the Archæological Department, the Mineralogical Department, and others; we have it in botany at Kew, and we have it at the Meteorological Office; but not in physics. There is not much in chemistry either, and no engineering except military engineering, that is recognised by the Government. It seems to me that Applied Physics is, one may say, the mark of this century, and physics itself has grown enormously this century. Because it has not hitherto loomed large in the public imagination is the reason, no doubt, why national recognition has not yet been attempted; but it seems to me that now the time has come for the Government to recognise this, as it has recognised other sciences, on a wide and broad basis.

902. (*Sir John Wolfe Barry.*) I gather you mean that, although the first aim might be in what you call pure science, these investigations would very likely have a very valuable effect upon the trade and commerce of the country?—Yes.

903. You have used the word "Arts." I presume you use that word in the sense I have just indicated?—Yes, entirely in that sense, not in the sense of Fine Arts at all. As to the quantitative determinations mentioned in my first answer, which are or may be useful in practice, I do not think we are wise enough to say beforehand what may be useful in practice. I think we must have some faith in that respect.

904. You gave as an example the discovery of this alloy as being an important matter which would be of great value in that particular description of Art?—Yes.

905. (*Mr. Chalmers.*) You speak about wealthy amateurs, and attach the greatest importance to their work; would you extend that to the universities; would you say that in this country, regard being had to the general feeling, you would look to the universities rather than to a Government institution to produce good work?—I would look to both.

906. There is not much precedent, is there, for Government work turning out very well in a matter of research on those lines—is there any precedent, indeed, for Government work in that direction?—Not for research in the sense of pioneering work, I think.

907. (*Dr. Thorpe.*) Perhaps I might put a case which would serve to bring out what I think Mr. Chalmers intends. There is the case, for example, of Regnault, who was subsidised by the French Government to do a large amount of physical investigation, which led to very important numerical determinations of great value to both science and industry; for example, all Regnault's work for the determination of the data connected with the steam engine was work which was done under the auspices of the French Goverment.

908. (*Mr. Chalmers.*) That was under the French Government, but do you think in England it is at all likely that Government subsidies and Government aid would tend to encourage the object that you have in view?—I think the Regnault work is eminently work that might have been done under this Government, surely.

909. You would say so, generally?—In spite of national peculiarities, do you mean?

910. Yes?—I would. I do think so. I think, for instance, that the University Observatories and Dr. Huggins's Observatory, and so on, are not calculated to do the same work as is done at Greenwich. There is a great mass of work that is quite properly done at Greenwich by the official staff, which otherwise would not be done at all. I think the Regnault work—highly organised investigations into the properties of materials, the properties of steam, for instance—is eminently work of a kind that I would like to see done at this laboratory. It is work that is constantly being referred to by all engineers, of course; they depend upon it for their knowledge of some of the properties of steam.

Addendum. [In so answering this question, I did not mean to imply that I thought the work would go on well under immediate Government *supervision*,—in a Government office, for example;—I do not take the word "national" as implying that. I take it as implying permanent and organised existence with national pecuniary aid, but under the immediate government of, say, the Royal Society or other suitable scientific body.]

911. (*Mr. Roberts-Austen.*) The whole of St. Clair Deville's work on aluminium was subsidised, if I remember rightly, at a time when the extraction of aluminium did not look very hopeful; is that a case such as you contemplate?—Yes, but I did not know he was subsidised.

912. (*Mr. Siemens.*) You mean that an institution like this should undertake what might be called systematised routine work?—Yes, exactly.

913. Not pioneer work?—No.

914. Simply the routine work, where the officials who do the work could be perfectly controlled so as to secure that they did a proper amount of work, but that work would be simply work which, though it requires to be done, takes time, and, therefore, no private individual could undertake it?—That is exactly what I mean; that is the chief part of the work that should be done there.

915. (*Dr. Thorpe.*) Supposing it were not found possible to establish an institution upon the wide, broad basis that you have indicated, is there not, in the actual work required to be done in connection with standardising the existing instruments, a considerable amount of investigating and researching work needed? For instance, there is a considerable amount of work required to be done in the investigation of the peculiar properties of glass in connection with thermometry. Supposing, therefore, to take a case, that the National Physical Laboratory were to concern itself merely with the question of the standardisation of thermometers, there would still be room, and considerable room, for work of an investigating character in connection with that subject?—Yes, I quite think so. I think that thermometers might be very much improved. I think it might be possible to make them of quartz instead of glass, if attention were directed to that sufficiently. Further than that, there is the platinum thermometer which has been privately investigated, chiefly in Canada of late years; but before that can become a practically applicable instrument all round, there is a great deal of experimental work that still has to be done.

916. That, perhaps, is true of other matters which are of practical importance?—I believe it to be true in a very great number of different matters. I think the sensitiveness of photographic plates for different wave lengths, and so on, might be tested. The makers might supply different films, and the films need only be tested at this institution. If the makers knew that anything of that sort was going on, it would encourage them to aim at improving their materials and their films, I think, in a way that they are not now, when they are chiefly criticised by photographic amateurs; if they knew they were under a real test and competition between one another, I think the production of sensitive photographic films for all parts of the spectrum might make considerable advances. That is only one thing. There is such a quantity that requires to be done; I have drawn up a list that I might send in of things that might be done at such an institution.

917. Things, do you mean, of actual, practical, immediate demand?—Well, certainly some are more immediate than others. As to the matter of urgency, that, I think, the Council would decide upon. There is far too much work to be done all at once. There is work for several centuries, but some of it is more urgent than others. All of it might be looked to to yield practically useful results sooner or later, because it always has been found when discoveries have been made that they have turned out to be practical and useful. Even if the investigation into the weighing of nitrogen had resulted in the discovery of argon at such an institution, would that not have been a justification for it, even if argon is not immediately useful in the Arts? One cannot always tell how soon things will become useful.

918. (*Sir Andrew Noble.*) I suppose photometric standards are a growing want, are they not?—Yes, I believe so. There is a good deal of work to be done in photometry. At present the best photometer comes from Germany—like so many things. The same way with our microscopes, we do not compete with the work of Zeiss; and so with the very finest optical glass, we do not do any of that in this country, I believe.

919. (*Mr. Chalmers.*) But all that was before the Reichsantalt, was it not—that goes back over 20 years?—The latest photometer I spoke of is since the Reichsanstalt was established.

920. As regards microscopes, for instance, they date back a good 20 years?—Zeiss's work, no doubt, does.

921. (*Mr. Rücker.*) Do you know whether those investigations into glass were subsidised by the Government?—I am afraid I do not.

922. (*Dr. Thorpe.*) To go back for a moment to your remark about argon, you surely would not regard it as the proper work of such an institution as is contemplated, that it should spend a very large amount of time in investigating what at first is a subsidiary point; that would not fall within its proper business, would it?—No, not the looking for argon, but I think it might be set to determine atomic weights with great accuracy.

923. Of course, as you are aware, it was the discrepancy which led to the pushing on of the work which eventually resulted in the discovery of argon; that surely is not the proper work of a person connected with such an institution?—But it was the determination of the atomic weights that led to the observation of the discrepancy. It is important, surely, for chemists to know the atomic weights accurately, and the atomic volumes, and such things?

924. Quite so, but then it is not desirable that a great amount of time should be taken in investigating the cause of such a discrepancy?—If it had definitely found the discrepancy, that would have been sufficient for the Laboratory; it might then have handed the subject over to a university—lots of people would have taken it up at that point.

925. You have had this question before you now for some years; have you thought about the possibility of the Kew Observatory being developed into an institution of the character you contemplate?—I have, but not with great first-hand knowledge on the subject. Mr. Francis Galton suggested about Kew, and it seemed to me a good suggestion that we should proceed by evolution rather than by fresh creation; but what the practical difficulties may be in developing Kew I do not know. They do not seem to me to be great, and it would seem to me a suitable locality—quiet and yet near London, available for foreigners, available for visitors, and with land also available on which additional buildings might be put. But if it is done, a very great enlargement of the present idea of Kew would be necessary—considerably more buildings would be wanted, with such a man as Lord Rayleigh as head of the institution, if it could be managed.

926. Would that not mean a very great departure from the fundamental idea of Kew?—I think it would mean supplementing it rather; the Kew work would still certainly go on.

927. Then in strict truth you would say a development of Kew?—A development of Kew it would be.

928. On existing Kew lines?—To some extent it would be by enlarging the kind of instruments that are tested. I believe that at Kew no real researches are carried on for the purpose of improving instruments, and that they only take instruments that are sent and report

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on them; also, of course, they carry on a continuous record of meteorological and magnetic phenomena. Both those things might be extended. Also their work might be supplemented by researches into the properties of materials, and by the occasional investigation of a physical constant or of a supposed physical law, whenever it became imperative that such an investigation should somewhere be conducted; unless it happened that a University professor or other person qualified was willing to undertake it, in which case it might be done by him.

929. (*Sir John Wolfe Barry.*) Do you think that the relation between such places as university and private laboratories and such a public institution as you have in your mind, would be something analagous to the relation between Greenwich and the other observatories?—Yes; exactly that.

Friday, 19th November 1897.

PRESENT:

Mr. A. W. RÜCKER, D.SC., F.R.S. (in the Chair).

Sir COURTENAY BOYLE, K.C.B.
Sir ANDREW NOBLE, K.C.B., F.R.S.
Mr. W. C. ROBERTS-AUSTEN, C.B., F.R.S.
Mr. ROBERT CHALMERS.
Mr. ALEXANDER SIEMENS.
Dr. T. E. THORPE, F.R.S.

Mr. L. BLAIKIE, *Secretary*

Professor G. Carey Foster, F.R.S.
19 Nov. 1897.

Prof. G. CAREY FOSTER, F.R.S., called; and Examined.

930. (*Mr. Rücker.*) You are a member of the Kew Committee, I think?—Yes, I am.

931. You were, I believe, a member of the original Committee of the British Association by which the ohm was determined?—Not during its operations; I was only nominally connected with that Committee.

932. But you are fully acquainted with its work?—Yes, I know the history of it pretty fairly.

933. You have, I think, taken some interest in the question of the establishment of a National Physical Laboratory?—Distinctly; it is a matter of great importance.

934. Would you kindly give your reasons why you think it desirable that such an institution should be established?—I think, both with reference to purely scientific matters and in connection with industrial advancement, it is desirable. We can take it for granted that the advancement of science means in the long run the improvement of industry. I do not propose to argue that point, but take it for granted. In all scientific work there is continual reference to elaborate measurements, and to a very great extent I think the time and labour of scientific investigators might be economised by having the purely numerical testing work done for them in the sort of way that it might be done by this proposed National Laboratory.

935. Are there any limitations to the kind of scientific work that you think should be carried out in such a laboratory?—My idea is that it should be confined, as far as that is practicable, to what one may call quantitative work—the testing of measuring instruments and the establishment of accurate standards of reference. Investigation in the ordinary sense, the investigation of new phenomena and attempts to discover them, I think, would be better left to individual initiative. It is not for that purpose, it seems to me, that a public laboratory, supported by national funds, is wanted; but rather for what one may call the purely routine work of testing measuring instruments and making careful examinations of standard values.

936. Is that work which you think could be carried on in the universities or colleges?—It has been already to some extent, but I think it could be carried on with very great economy of labour by a body specially devoted to that kind of work.

937. With your knowledge of the arrangements at Kew, do you think that Kew adequately satisfies all the demands of this sort that may be made?—I think that Kew is doing the sort of work that it seems to me to be desirable should be undertaken by a national establishment, but by no means on the scale that would be useful.

938. Could you give us any instances in which you think Kew is hampered in such matters?—Kew is fully occupied with its present work.

939. Its resources, you think, are fully employed?—From what information I have, as a member of the Kew Committee, and from hearing pretty frequently as to the state of things there, I believe it is impossible with the present establishment to undertake any considerable extension of work, having regard either to space or to staff.

940. Do you think any specific part of it, such as the thermometric work, for instance, requires enlargement?—I do. We have at present at Kew no means of giving an independent test of the accuracy of a thermometer outside the range from melting ice to boiling water, and the Kew Committee have recently sent an investigator to work at Paris at the Bureau International just for the sake of studying the hydrogen thermometer, which does not exist at Kew.

941. In the case of the magnetic observations which are carried on at Kew, do you think that the establishment there is up to modern improvements?—I am afraid it is not by any means. I understand that quite recently differences between the indications of different instruments have come to light which we were not aware of before to the same extent; those are matters that ought to be investigated in a laboratory of the proposed kind.

942. And that question is one which you think could be properly taken up by a National Physical Laboratory?—That is one question of the kind I had in my mind as desirable for this Laboratory to take up.

943. You will, perhaps, say that the measurement of magnetic field, which is one of the operations there carried out, is fundamental in the determination of magnetic and electrical constants?—Distinctly so.

944. And, therefore, it underlies trade measurements, which, to a certain extent, depend ultimately upon it?—It underlies nearly all electrical measurements more or less directly, and therefore it is a very important industrial question.

945. With regard to electrical and magnetic instruments, do you think it would be desirable that they should be tested more than they have been in the past?—I think we want some more independent authority than exists at present. The Board of Trade have recently undertaken the testing and standardising of electrical instruments, but the Board of Trade Department for that purpose is not an independent scientific authority. They have certain standards, and you may say gauges with which they compare instruments sent to them; but they have no means of testing for themselves what the value of their standards may be.

946. Do you think the standardising of electrical instruments requires investigation to be carried on in order to improve it?—I do. That, I think, is of very great importance; for instance, the absolute value of the unit of electric current, the ampère, now practically rests upon Lord Rayleigh's determination of the electro-chemical equivalent of silver, but that I do not think has been determined with the certainty and accuracy which is now desirable.

947. And what reason would you give for thinking that that is work which could be best done in an institution of the kind proposed, rather than in an ordinary laboratory?—I think it is work that wants determining not once for all, but rather that there should be a permanent establishment where measurements of this kind can be carried out. It is not exactly on the same footing as, say, the standard of length which can be embodied in a bar, as being the distance between two defined marks. You

cannot set up a standard current and compare other currents with it; there is the question of carrying out a measurement from time to time.

948. Do you think it is of practical importance to trade that this measurement should be better made in the future than it has been in the past?—I am not in a position to say whether the degree of accuracy which has already been attained is sufficient for trade purposes, but I suppose there is no doubt that for scientific purposes we want at each stage the utmost attainable accuracy; and, as I said before, I think there is no doubt that scientific advances react upon industry, and that what is required for science is indirectly required for industrial purposes.

949. One of the questions that is referred to us is whether or no this institution should undertake the systematic determination of physical constants; what is your view on that point? Do you think that ought to be done?—That, again, I think, is distinctly the sort of work that it is desirable that this laboratory should carry out. The requirements of science in this respect are continually advancing, and what was a sufficiently accurate determination at one time is no longer so after a lapse of a few years and the advancement of collateral branches. I think there are many cases where repetitions of determinations, quite apart from the hope of getting increased accuracy, are desirable with a view to ascertain whether or not what we speak of as constants are really so, or whether some unknown change is going on.

950. Do you think that scientific research and its application to trade is at present hindered by the fact that our knowledge of those constants is imperfect?—I cannot name a concrete case where that is so. The whole question of thermometry which we were speaking of before is in a very unsatisfactory state. I can quite well imagine that difficulties might arise in manufacturing processes as to the exact definition of things of commercial importance. Electrical measurements are of very great commercial importance nowadays.

951. (*Mr. Chalmers.*) But you cannot point to a concrete instance?—I am not sufficiently acquainted with what trade operations are.

952. (*Mr. Rücker.*) Do you consider that scientific research, at all events, would often be benefited if information as to the constants that are required could be more easily obtained than it is now?—A very great number of numerical data are continually required, to which references are continually made in scientific work, which are imperfectly known.

953. With regard to the management of such a laboratory if it were established, have you any views on that point: do you think it desirable that there should be a man of high scientific attainments at the head, or that there should be, rather, several of less scientific rank?—I have not specially considered the direction of such an establishment, but it seems to me that a man of considerable scientific attainment would be necessary as the executive head, and probably—but I am not very confident in the matter—it would be well that he should work under the direction of a small committee of experts—perhaps a committee nominated by the Royal Society with some such constitution as that of the present Kew Committee.

954. It has been suggested that such a body as that should report annually to a much larger body, representing many branches of science; do you think that would be desirable?—That is a new question to me; I do not see off-hand any particular advantage in that.

955. You would be content with a body nominated directly by the Royal Society or by the Royal Society and some of the great technical institutions?—So far as a laboratory of the kind proposed would have a technical connexion, I think there ought to be a representation of the industrial bodies as well as the purely scientific bodies on it.

956. As regards the site of Kew, do you consider that as a satisfactory site for such an institution?—In the main, I should think it is. There is no doubt that most of the work, if not all, that would be carried on in the laboratory requires a site undisturbed by traffic—not only undisturbed by mechanical tremors, but undisturbed magnetically or electrically in the sort of way that might occur in any large town nowadays where great electric currents are continually being employed. So I should think that probably the Deer Park at Kew is one of the best situations within that distance from London that is likely to be available.

957. Is it possible that some of the operations carried out in the laboratory might conflict with the accuracy of the existing magnetic observations?—If they are carried on within a very short distance of each other they would probably.

958. Then the institution ought probably to consist of more than one building with a considerable distance between each?—I should think that would be almost essential; I say that with confidence.

959. (*Sir Andrew Noble.*) I gather from what you said that, although you think the Director of the Laboratory ought to be a man of science, you would be perfectly contented that there should be at the same time a committee similar to that which governs Kew, governing the physical laboratory also?—That seems to me a desirable organisation. You certainly want a man of very considerable scientific attainments as the executive head.

960. The question of determining physical constants is a very large one; there are an immense number of physical constants of various degrees of importance, and I suppose you would consider it desirable that that governing body to which you have referred should determine what particular physical constants it is desirable to examine specially?—Yes; I think that they would determine special questions to be investigated in the laboratory from time to time. There are many things that it would be desirable should be done that could not be carried on all at once. Such a Committee as is spoken of would probably decide as to what should be done at any special time.

961. That is exactly my meaning. With regard to Kew I think everybody will agree with what you have said that the nature of the work there and the way it is carried out is exceedingly good, but I understand also from your evidence that you consider it is very limited in extent?—Of course, that is a comparative term.

962. Exactly; but taking the instance you yourself cited, that of thermometers, it is nearly entirely, except by special concession of the Superintendent, confined to meteorological thermometers, is it not?—And clinical thermometers.

963. Yes, clinical thermometers also; I beg your pardon, that is the largest of all. But with a comparatively narrow range, like the meteorological thermometers, a comparison with a gas thermometer is not probably of so great importance; but I suppose you would say that it is desirable that they may be corrected by the gas thermometer if they had one at Kew—in fact, that the graduation should be corrected? At present they take, as you said, between the boiling point and the freezing point, and after due attention is paid to the calibration of the thermometer, if the thermometer were absolutely correct, they would simply divide it into equal divisions?—Yes; but that does not give a perfectly definite scale of thermometry; it depends not only on the indications of a thermometer treated in that way, but it would also depend on the quality of the glass.

964. Dr. Chree went pretty fully into that; but what I mean is that they are not compared with the gas thermometer?—At present they are not. The corrections at present given at Kew are arrived at exactly as you say by the determination of the freezing and boiling points, and by the calibration of the stem.

965. For many purposes you want a thermometer travelling over a very much greater range, and if, for instance, you use one of those mercurial thermometers which go up to 500 degrees Centigrade, in that case it is very important that the thermometer should be corrected by the gas thermometer; but Kew has no power of doing that?—At present none at all.

966. If experiments made in this country are compared with experiments made in Germany and France, where, as I understand, these thermometers are compared with a gas thermometer, in that case we may have discordant results; and it would be rather a scandal to this country that they should exist?—That is quite my view.

967. A point I want to draw attention to, although I did go into it with the Superintendent of the Kew Observatory, is that if you want at present any thermometer for delicate calorimetric experiments, a thermometer divided, for example, to one hundredth or one thousandth of a degree, you are compelled absolutely to go abroad for it, as they cannot be produced in this country; that is so, is it not?—As far as I know they are not produced. I am not able to say they cannot be produced.

968. (*Dr. Thorpe.*) You have not got any in your collection at University College?—I have nothing divided finer than tenths of a degree.

969. (*Sir Andrew Noble.*) I have got one to thousandths, and we are compelled to go to Germany for it. I am now going to a point rather more connected with actual practice; although I entirely agree with you that nearly every advance in science is for the interest of manufacturers, do you think that a laboratory of this sort should undertake experiments requiring a long time or very great accuracy? I will give as an instance experi-

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ments as regards the strength of material—the effect of stress commencing, say, near what is called the elastic limit, and extending over a very long time; we know that there is a very considerable variation, but you would require a very long time to establish what that effect is?—I think that is one of the classes of work which would be specially suitable for such a laboratory, and that it is work which cannot very well be carried out under existing conditions. It is work which requires a long-continued series of exact observations carried out upon an invariable system.

970. I mention that because when I tried once to carry out at Elswick an experiment of that nature, we altogether failed on account of the effect of either or both the railway and the large hammers; they disturbed us so much. Now, the physical laboratory at Kew would be free from anything of that sort; and is that the class of experiment you would consider it important to carry out at such a laboratory?—That is specially a sort of experiment, I think, that cannot under present conditions be very effectively dealt with; it is the sort of thing for which this laboratory seems to me to be desirable.

971. (*Sir Courtenay Boyle.*) I have very few questions to ask, and they are more from an administrative than from a scientific point of view. What is the function which in your opinion the State should be charged with in the matter of standardisation? I will put it in this way: Is it the duty of the State to do more than to see that standards, as distinguished from samples, are accessible and available?—I think it is; I may, perhaps, take as an example the electrical units. I think it is desirable that there should be a publicly supported laboratory where the fundamental electrical quantities may not only be compared with each other, but actual independent measurements made of them; for instance, suppose that all the copies of the standard ohm were destroyed, that the laboratory should be in a position to reproduce an ohm from the theoretical definition of it.

972. But that is a reproduction of a standard?—Yes, but it is a sort of work that is not provided for as far as I know by any existing public department.

973. It ought to be at the Board of Trade, ought it not, under the arrangement with which you and I had something to do?—At the Board of Trade they compare a professed ohm sent in to them with their own standards; but they do not profess to check the value of their own ohm, they take their standards for granted.

974. Supposing all the copies of the metallic ohm were destroyed, would not the Board of Trade be in a position to replace the coil?—I think not.

975. You think they ought to be?—I think they ought to be.

976. That is the reproduction of a standard?—Yes.

977. That is a great deal less than the verification of instruments. We have had a great deal of evidence to show that much good work is done by the testing of instruments, that is to say, the testing of a clinical thermometer when it comes up to a certain sample; but that is a different thing from a standard, and the State does not fix what the standard clinical thermometer should be. Do you think that the State ought to undertake elaborate work in the testing of individual instruments, or that it should confine itself to standardisation in the true sense of the term?—I think such work as is done at Kew in the testing of instruments, thermometers, among others, is extremely useful work; and I think that if measuring instruments of other kinds could be tested and certificates of their performance issued by some trustworthy authority——

978. I am afraid I must press you—by a trustworthy authority, I agree with you absolutely, but should it be a State authority?—I think it should be an impartial authority, independent of any industrial interests, and I think upon that account amongst others it had better be a State Department than a private institution.

979. Even a Department having such a high standard as Kew Observatory has at the present moment, with assistance given by the State?—An institution administered more or less on the lines of the Kew Observatory, and with sufficient pecuniary support, is what I think is needful. I do not know where the support is to come from so well as from the public funds.

980. Is there not a certain amount of mischief sure to ensue from the state affixing its *cachet* to a particular individual machine used for commercial purposes—I use the word "machine" to cover instruments also—is there not a certain amount of evil in that?—I do not think it would amount to the laboratory guaranteeing the quality of an instrument. They would say what it does; they would say it professes to indicate an electric current of such and such a strength; they would say what the errors of the instrument are; but there would be no recommendation that this is a very good thing or pretty good. They would not attach any adjective to it; they would merely say how accurately it does what it professes to do.

981. But is there not always something more read into a State certificate than exists? Can you answer that question—I am afraid I can if you cannot?—That is to the credit of the State if it is so, is it not?

982. Is it an advantage commercially that the State should give certificates which although carefully limited in extent are held to be of unlimited value?—I think it is very much on a par with the testing of chronometers, say, at the Greenwich Observatory. The work that is done there might quite conceivably be done by private organisation, but it is found to be on the whole an advantage that it should be done by an official department.

983. Then you would have a State Department in which could be tested the performance of instruments also?—Yes.

984. Thermometers, polarimeters, viscometers, cathetometers, hydrometers—all of them?—I do not say every possible instrument that can be constructed, but there are a very large number that might usefully be tested.

985. Granted the establishment of a State Department would not every instrument maker insist on having his instruments tested by that department?—Makers do not all insist upon having their thermometers tested at Kew; some like it and some do not.

986. Is there any chronometer maker who thinks his chronometer will come up to the test who does not test it? I again press you. Would it not have to be an enormous department if it undertook to test the behaviour—I will not put it higher than the behaviour—of instruments of all sorts, and to issue a certificate of some sort or kind; would not that have to be a gigantic department?—There is a very great variety of work that could usefully be done in that way, but I should not myself think it desirable to undertake to test every possible instrument or class of instrument. It should be only those which by the nature of the case can be expected to undergo a severe and exact test.

987. Is it or is it not, in your opinion, more probable that the work would be more carefully done, and done within better limits, if done by voluntary effort encouraged by the State than if done by the State itself?—I think the immediate administration of such a laboratory should not be in the hands of the State.

988. One word, please, about the determination of physical constants; if the State undertook the determination of physical constants, how would you limit that work—would not the State be bombarded with requests to determine a number of constants which are not of much value?—I would have something between the State and the public—I would have a Committee of Direction.

989. Does not that fall back upon voluntary effort encouraged by the State—subsidized, if you like—paid for and encouraged by the State, rather than by the State itself?—Yes; that is what I would come to. I want the laboratory to be supported by the State, but to be administered by a committee of experts.

990. Then if you had the responsibility of the State with the advice of the experts you might have a little friction, might you not—the unwise men of the State would refuse to carry out the advice of the wise men of the committee?— I think such questions would settle themselves in the course of time.

991. (*Mr. Roberts-Austen.*) You took a prominent part, did you not, in connection with the British Association Committee for the verification of the resistance pyrometer?—Yes; a good many years ago.

992. That would be essentially work that would have to be undertaken by this laboratory, would it not?—That is a sample of the sort of work that I think they might very usefully do.

993. (*Mr. Chalmers.*) At present, I believe, you have a stamp with the initials of Kew Observatory put on the thermometers and other things which you test?—Yes.

994. Do you attach any importance to that being made a Government stamp—a crown, for instance, as an emblem? Do you suppose it would have any more value in the minds of the manufacturer and the public if there were such a change?—I do not know that the particular shape of the mark is of importance.

995. The fact that it was a Government crown instead of simply the letters K. O. would not carry more weight, you think?—I think the people who use instruments which are verified at Kew Observatory know pretty fairly the nature of the test that they have undergone; at least,

they know the nature of the authority that they rely upon, and they trust that.

996. From the scientific point of view, I take it, there is no question that taking the words here, the National Physical Laboratory, the word "National" would have no weight at all in the scientific world. What you want is a physical laboratory?—I think it should be National, rather for the sake of getting funds.

Addendum.—[I should like to explain this answer by adding that, in my view, the proposed laboratory would be useful to the nation at large, not to special individuals or a special class. It seems, therefore, fair to look to its being supported by public funds.]

997. (*Dr. Thorpe.*) I should like to ask one question to elucidate what I think there has been some misconception about, and that is, as to the degree of precision to which these standards should go. You have been asked the question whether the actual definitions of the electrical units or standards of capacity were not sufficiently precise at present for practical purposes; I gather that this is your opinion—that these standards should really, in the matter of definition, be actually ahead of present trade requirements?—Electrical standards depend on theoretical definitions, and any actual instrument can only make an approach more or less exact to the definition.

998. But it is desirable, of course, that the approach should be as close as possible?—For scientific purposes I think we should never be satisfied with anything less than the greatest attainable accuracy.

999. Just as at the present time the standards of mass and the standards of length and the standards of capacity are defined, and are actually existing far and beyond what you may call the necessities of trade requirements, so these other standards should occupy a similar position—that is your idea?—Yes, that is quite my opinion. If the thing can be made more accurate, it would be the function of this laboratory to endeavour to make it so.

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1000. (*Mr. Rücker.*) Is it not desirable that the approach to the theoretical standards which is obtained in the case of any legal standards should be greater than the actual necessities of trade requirements?—I should certainly think that we ought not to limit our attempts to obtaining accuracy of standards by trade requirements; the only limit is the limit of the possible accuracy to be obtained.

1001. (*Dr. Thorpe.*) What I am really leading up to in this—it is all bearing upon what you said earlier as to the scope of the work of this proposed laboratory—that you would limit it to, so to say, immediate practical necessities, and that investigation in its broadest sense you would exclude from the sphere of its operations; but you would not exclude, I take it, investigations directly bearing upon the definition of your standards?—Certainly not. The distinction that I made is only a very broad one. You cannot completely separate standardisation and measurement from investigation, or investigation from standardisation. Frequently investigations will be necessary for establishing the best and proper way of carrying out these standard measurements.

1002. The last question I wish to put is, as regards the method of government and the administration of this place. I gather there would be no greater administrative difficulty in regulating the work of this proposed laboratory than there is in regulating a State-aided institution like the Royal Observatory; just as the Royal Observatory at Greenwich is, to some extent at all events, controlled by a Visiting Board, so this might in the same way, although a State-aided institution, be controlled on something like the same principle?—That is my idea—that there would be a responsible Director or head who would answer, for example, to the Astronomer Royal, but that he would report from time to time, and perhaps be to some extent guided by a committee of experts.

Professor SILVANUS THOMPSON, D.Sc., F.R.S., called; and Examined.

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1003. (*Mr. Rücker.*) You are the Principal of the City and Guilds of London Technical College, Finsbury?—I am.

1004. And a Vice-President of the Institution of Electrical Engineers?—Yes.

1005. Among many other things you have given special attention to the dynamo and to the technical application of electricity?—Yes.

1006. Do you think it desirable that there should be an institution for the verification and standardising of physical instruments?—Yes, it is very desirable.

1007. Can you put shortly your main reasons for that?—It is very desirable because the existence of such a place would tend to the improvement of the industries that either work for or are dependent on the use of instruments of precision.

1008. Do you think it should be on the general lines, say, of Kew Observatory?—Yes, on the general lines of the Kew Observatory; but undertaking certain work that the Kew Observatory does not undertake.

1009. What particular kind of work would you add?—I should extend the work to other instruments that are not at present taken in either at Kew or anywhere else. Of course, one knows that at Kew the work does not overlap the work of the Electrical Standards Laboratory at the Board of Trade; but there are certain electrical instruments that are not standardised at either place, and any establishment for the general standardising of physical instruments would, of course, include such.

1010. Could you mention what instruments you have specially in mind?—There are various kinds of galvanometers, for example, that are not treated at the Board of Trade; then there are hygrometers, hydrometers, and numberless optical instruments which are not treated at either place.

1011. In the case of the optical instruments, do you think there is any special need for standardising them?—I am sure there is. I have long had that on my mind. Some ten years ago I made a proposal to the City and Guilds Institute that they should create an optical testing laboratory. At that time electrical testing laboratories had not been in existence very long, but there were at least two, if not three, in London, and it seemed to me that there would be a great use for an optical testing laboratory. There is no place in the whole of London, or, so far as I know, anywhere outside Cambridge, perhaps, where one can take his optical instruments and have them verified. Even the laboratory at Kew would not propose to undertake that kind of work. I proposed the creation of such an optical laboratory which would involve the construction and design of a number of pieces of apparatus for testing the optical properties of materials, the accuracy of instruments, focal lengths, aberrations, and so forth of lenses, the performance of instruments, the truth of optical surfaces, the exactness of curvatures, and a number of things of that kind. For some of these things, of course, instruments exist, and for others instruments would have to be designed, and it seemed to me that it would be a great help to the optical trades in London, particularly, if such an optical laboratory were created. However, the City and Guilds Institute did not seem disposed at that time to find the necessary funds, and nothing was done. Then, two or three years later, at the time when the Charity Commissioners were proposing to erect technical institutes in various parts of London, I gave the draft outline of this same scheme to Mr. Cunnynghame, who was then working with the Charity Commissioners, with the suggestion that such an optical laboratory should be created in Clerkenwell for the benefit of the optical trades in London, and associated with the scheme which they then had in embryo for making a technical institution in Clerkenwell. I had an acknowledgment from Mr. Cunnynghame of the receipt of the draft scheme, but I have never heard anything more of it from that day to this. I am quite clear that it would be a useful position for an optical testing laboratory in London.

1012. In the case of any new glass being introduced, would it be a place where the optical properties of that new glass could be tested?—Certainly.

1013. Do you know at all whether such an idea would be favourably received by the optical manufacturers?—I have not talked with them in general, but I have talked with one or two, and one manufacturer certainly complained to me that there was no such place where he could get things tested. I have on several occasions tested things myself for him; he has asked me to verify the properties of lenses.

1014. In this new institution do you think any work in addition to standardising work should be carried out?—It would be desirable, when you have an institution for standardising work, that part of the duties of that institution should be the compilation of statistical information on scientific things. It would be somewhat of the nature, I suppose, of a statistical research, if I may call it so; it would not be research in what one may call the pioneering

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sense—not pioneer research, but it would be the taking up of research at the point to which some original researcher had carried it, and then doing the drudgery of reducing to direct observation and tabulating statistics of the various things that might come under research.

1015. That of course might involve a very great deal of work; how would you select the particular objects to which the institution should devote itself?—That, I imagine, should be left to the director, whoever he may be, in the first instance. The director would naturally be anxious that all such work should be made as useful as possible.

1016. You mean the director or the governing body, I suppose?—Or the governing body.

1017. You do not anticipate then that this would mean a very large operation necessarily?—No; in fact, it should be exactly as large or as small as would be desirable.

1018. Nevertheless, you think it would be useful even when carried out on a comparatively small scale?—Certainly, there are many things on which statistical information is most desirable about which very little information exists.

1019. (*Dr. Thorpe.*) Could you give an illustration of what is in your mind?—I could give an illustration. Only yesterday I was asked by one who wanted to know it for commercial purposes if I could tell him what was the specific electrical conductivity of graphite of different degrees of purity. I said, "Well, I am afraid such information does not exist; I know in general about the order of magnitude it would be; I have done it myself with graphite, but I do not think that anyone has ever gone to the labour of preparing specimens of graphite and testing them and tabulating the results."

1020. (*Mr. Rücker.*) Nevertheless that of course would be useful for trade?—It would be very useful to the electrical industry to have such information for reference just as we have, not only for the ordinary metals that are used, copper, silver, iron, and so forth, but even for the alloys. But we have no such information for carbon, and there are a great many liquids about which we have no statistical information as to their conductivities. It involves no research in the true sense of the word to discover these things—the method of research is perfectly well known, but it wants an amount of skilled labour expended continuously for perhaps some months together to collect the data on these things.

1021. Do you think there would be a number of such problems which could be selected and which would have special reference to standardising?—Certainly, they would always be occurring.

1022. Have you any reason for thinking this work could not be well carried out at the Universities or Colleges, or by other teaching bodies?—I think it would be a great mistake to carry it out in an establishment the prime function of which was education.

1023. Why?—Because I think the two things would interfere with one another. This is routine work of a particular kind, and whoever is engaged on it ought not to be called off on other things. Further than that, the research work that is done more particularly at the Universities by men who are working for a thesis, or working at what is called ordinary research, is work of a limited kind; they want to pioneer and they cannot go on for many months continuously at what one may call the drudgery of research. It is the drudgery of research for which such an institution as this is perhaps more desirable.

1024. Then coming in greater detail to the management of the establishment, do you think there ought to be a director of the very highest scientific attainments?—Yes, judging by the experience of Germany, certainly.

1025. But you would have him under a committee; have you formed any view as to how such a committee should be appointed?—No; I cannot say that I have.

1026. But you would have a scientific committee controlling him?—I would not say an exclusively scientific committee—a scientific committee certainly, but not necessarily made up of professional scientific men.

1027. (*Sir Courtenay Boyle.*) You have used the words verification and standardisation; do you draw any distinction between the two?—Verification, I think, I should use in some cases to mean the verifying of things that had some professed value; and standardisation I should rather apply to a measuring instrument which professed to indicate a great many values in terms of some standard.

1028. That is the way in which you would use the word "standardisation"?—I think so; for instance, the focal length of a lens is supposed to represent a certain number; you could compare that with a standard and verify it, but you could hardly standardise it because it involves only one point.

1029. You do not use the word standard in the sense of a statutory standard?—No, it is rather comparing with a statutory standard or with something that is supposed to be an exact copy of a statutory standard.

1030. Are there statutory standards of lenses or thermometers?—A lens is not a thing like a foot rule, which has many measurements upon it.

1031. Is there a statutory standard of one?—No.

1032. When you say you compare it with a standard you do not mean that you compare it with a statutory standard?—I think I should call a comparison of a divided scale with a standard, standardising.

1033. Although the standard was not a statutory standard?—Yes. I am afraid I use the word standardising in more than one sense as meaning not only the comparison of one particular point, but verifying the scale of it throughout.

1034. (*Mr. Rücker.*) The statutory standard which you would use in the case of a lens would be a standard length?—Of course.

1035. The only statutory standard required in the case of the focal length of a lens would be a unit of length?—Certainly.

1036. (*Sir Courtenay Boyle.*) I am putting this question because we have all been using the words standard and standardisation in several senses, and I think we have rather bothered ourselves in consequence—I know I have myself. I put it to you in this way: Is it the duty of the State to do more than see that the statutory standards wherever they are required, exist; is it the duty of the State to see that instruments come up to sample or to issue any certificate of the behaviour of instruments?—I think that is a question of politics rather than of science.

1037. What the committee have to consider is, what is the view of you learned gentlemen?—My opinion is that it would be extremely advantageous to the country if the State would undertake such things.

1038. Why? Would it be better done by the State than by a body of scientific men uncontrolled by the unwise non-experts which State officials mostly are?—I do not think it would be done so systematically by private enterprise.

1039. Is not a false impression likely to be created if the State stamps or certifies instruments as of a certain behaviour?—I do not see why a false impression should be created.

1040. However carefully you limit a certificate given by the State is not more read into it than there is in it, and it is not generally taken that if the State certifies a thermometer to behave in a certain way that that becomes a State guaranteed thermometer, and is excellent for all purposes—is that not the way it works?—I do not see why more should be put upon it than it implies. If you guarantee a thermometer on a particular date that obviously does not guarantee it for all time.

1041. If the State tested all these instruments, would there not have to be an enormous department to test all the instruments that are used in the scientific or commercial world and to see whether any instrument came up to sample or was accurate—would that not be an enormous work for the State?—If you undertook to do everything it would be a very large establishment, but the work of the establishment might be curtailed and limited at any point at which it seemed desirable. The Kew Observatory at present limits itself to certain things.

1042. That is a voluntary body with limited funds, but the State is supposed to be an involuntary body with unlimited funds?—I do not see why you should take it as an involuntary body.

1043. Take the determination of physical constants, you say it is very desirable that there should be a power of determining the electrical resistance of graphite?—Yes.

1044. That being so, is it not desirable that the electrical resistance of all sorts of metals and alloys and manufactured articles should be determinable by that same body—take vulcanite, for instance; if it is necessary to determine the electrical resistance of graphite, would it not be necessary to determine the electrical resistance of vulcanite—a manufactured article?—It would be desirable.

1045. That being so, all other manufactured articles too?—Not necessarily all. There are certainly some objects which are more important than others, because they are used as materials in specific lines.

1046. All that can be brought forward with any degree of reasonability—vulcanite, certainly?—Yes, certainly.

1047. If electrical resistance has to be determined, the behaviour of metals under stress and under pressure and under hammering would also have to be determined?—Yes, certainly.

1048. Would not the tendency of that sort of laboratory be to grow to an unlimited extent?—No; I think it would be limited by circumstances—by the will of the Director or of the Committee who govern it, and by the funds placed at its disposal.

1049. Do you think the State could actually limit its operations?—Certainly it can, certainly it does.

1050. (*Sir Andrew Noble.*) Following Sir Courtenay Boyle's questions, would it, in your opinion, be a proper division of labour, if I may say so, between the Board of Trade, for example, and the physical laboratory that we are contemplating, if the latter supplied the Board of Trade when necessary with the standards to which they were to refer, and the Board of Trade itself carried out the comparison with the standards for the public? I may add, before you answer the question, that with regard to the extent of this work there is no reason why the Board of Trade should not charge a certain fee to everybody who wanted his instruments examined, and so make that part of it a self-supporting establishment. Of course, that might be done, as the Government might decide, either by the physical laboratory or by the Board of Trade?—Am I to assume that the custody of the standards would rest with this establishment? Is that involved in your question?

1051. I suppose if you get a standard at the physical laboratory the Board of Trade would have to have a duplicate, and it would be the duty of the physical laboratory to see, whenever called upon by the Board of Trade, that the two standards were in accordance?—Yes, it is most desirable that it should be so.

1052. The point I am driving at is simply this: I want to see if Sir Courtenay Boyle's reasonable fear of considerable expense and a great deal of trouble might not in some way or another be met, and whether the expense would not disappear if either the Board of Trade or the physical laboratory, as I said, charged a fee for the comparison with the standards of the various instruments submitted?—Yes, that would to a large extent be self-supporting, but the other department—the department of calculating and tabulating data of physical constants and the like—would hardly be self-supporting.

1053. Clearly not. I am only confining myself to what I understood to be Sir Courtenay Boyle's difficulty, and I think that part of it might be made self-supporting. If it should be found inconvenient, which I fear it might be from the Board of Trade necessarily being in a large town, as electrical instruments might be disturbed by vibrations or large electric currents, and so on, that part of it the Board of Trade might delegate to the physical laboratory to do; but in either case, what I want to make out is that I see no reason, as a manufacturer myself, why the mere comparison with the standards should not be self-supporting; what is your opinion?—I see none at all.

1054. Of course, I fully understand with you that the determination of the standards themselves initially would be a thing that would not be self-supporting; that would be a cost and a charge?—Yes, it would.

1055. You mentioned in your evidence just now that you thought an establishment like what we are contemplating should test hygrometers and hydrometers?—Yes.

1056. Take a hygrometer, for instance. What hygrometers do you particularly refer to, because I rather understood from the evidence of the Superintendent of the Kew Observatory that the only hygrometers, if you can call them so, that they examine at Kew are the wet and dry bulbs; but would you refer to something else?—I include such things as wet and dry bulb thermometers and Dines' hygrometer. I do not know any others as being worth naming.

1057. I think that the most accurate I know is Regnault's?—Dines' is practically a modification of it.

1058. I do not know it; but I do know Regnault's, and that is accurate. Then hydrometers, of course, we all know, and it is very desirable that these should be capable of examination. I come now to what you said about optical instruments. You said that you believed—and I quite agree with you—that the best opticians would welcome such an examination of their instruments. Take, for instance, a microscope; if you have your object glasses and so on examined, you would sweep away a great deal of the rubbish that now floods the public, and any observer who sent his microscope could have object glasses, eye-pieces, and so on, examined. Of course, that would be done for a charge; but would you contemplate that class of work?—Yes.

1059. There are three things that should be done. First, to test the mechanical construction of the microscope; secondly, to test the object glass; and, thirdly, if you care to do it, the eye-piece; but, of course, I need not say the object glass is the main thing. I think that is a form of standardising, if I may use the word, which the better class opticians, such as Ross, and Beck, and so on, would gladly adopt, because it would enable their work to be examined and standardised?—The best opticians would certainly welcome it.

1060. (*Mr. Chalmers.*) Would it be possible, do you think, to limit this standardisation or verification, as the case may be, to English-made things? Would it not be possible for foreign makers to send their things over too?—I see no reason why they should not.

1061. (*Sir Andrew Noble.*) You see no reason why they should not if they paid for it?—That is so.

1062. Then I have understood your evidence to be that you think the Director of a physical laboratory should be a man of very high scientific attainments, but that he should be controlled by a governing committee, which might be appointed, for instance, by the Royal Society, as is the case at Kew?—I see no reason why not; but I have not really considered the point of the governing body at all.

1063. (*Mr. Chalmers.*) Your acquaintance with Kew would not lead you to suggest any important modification in the mode of the government of the future extended body? You have got Kew under a certain government; do you think it need be altered if you extend its scope somewhat?—It has not occurred to me that there is any necessity for it.

1064. (*Sir Andrew Noble.*) It would probably have to be extended, because at the present moment Kew devotes its attention to two things, I think you may say—terrestrial magnetism and generally meteorology, chiefly thermometers, barometers, and so on; but if it were enlarged you would require, I think, to put upon the Committee some men who might be conversant with different branches of science; but, however, that is, perhaps, another point. I have only one more question to ask you, and it is one that I ask because it is a point that I have known arise frequently in commercial matters, and that is the standardising, or, rather, if I may use the expression, the determination of the candle power of arc lamps. The question has frequently arisen with search lights, and there has been a very great variation in the determination, but I imagine that it would be very desirable that the physical laboratory should undertake the examination of such instruments?—As photometers?

1065. Yes?—Photometers are optical measuring instruments, and I do not see why they should not come within the ken of an optical testing laboratory.

1066. Would you bring search lamps into the category?—No, I would not bring search lamps in; but I would bring the photometer that tests them into the category of instruments to be examined at the laboratory.

1067. (*Sir Courtenay Boyle.*) Do you think a photometer ought to be standardised—that there ought to be a standard photometer?—There ought to be several kinds of standard photometers, certainly.

1068. There is not a standard photometer now of any sort or kind, is there?—There is a standard candle.

1069. (*Mr. Siemens.*) If the laboratory is suffering from over-work, it can be easily checked by making the charges higher?—Clearly.

1070. Then, also, if the laboratory is an extension of Kew, ought not there to be some practical people on the governing body—I mean not only scientific men, but also those who represent the commercial side?—I think I have said I saw no objection to there being others besides the professional physicists upon the committee, but I really have not considered the question of a governing body.

1071. I just want to bring that in, that I think the practical side ought not to be neglected?—I see no objection to their being represented on the governing body.

1072. I should prefer your saying that it was desirable?—I will say that it is most desirable.

1073. (*Dr. Thorpe.*) You are familiar with the working of the Kew Observatory and its system, are you not?—I have once been inside it, that is all I can say; I am afraid I do not know much more.

1074. Is there any particular and pressing demand that you can speak to which an enlarged Kew Observatory could, with profit, take up other than, for example, optical standardising?—Yes, there are several things, I think. One is the standardising and calibrating of other electrical instruments than those which are at present undertaken by the Board of Trade. The Board of Trade, for instance, will verify—at least, I suppose it does—ampère meters and volt meters for the purposes of electric lighting and power, but I do not think it concerns

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itself at all with the instruments that are wanted by medical men—for instance, milli-ampère meters.

1075. (*Mr. Siemens.*) Does the Board of Trade do that work at all? It only tests recording meters?—I understand that it does more than that.

1076. (*Dr. Thorpe.*) Is there any other class of work that you think might also be undertaken with profit?—I have said instruments of precision in general, but I do not feel disposed to specify further—on the instrumental part of it, that is to say. There is one thing I would like to mention; on the question of the determination of constants there are certain things that cannot well be undertaken at the Universities because they involve a very long expenditure of time in secular experiments going on over many years, to verify the properties of materials so far as they are liable to change with time.

1077. (*Sir Andrew Noble.*) I asked some questions upon that very point of the previous witness, Professor Carey Foster?—I was not aware of it.

1078. Those questions related to the secular variation of material, under stress among other things?—It is one of the things that has occurred to me that might very well be under the care of a permanent bureau of some kind, rather than left to haphazard research at the universities or anywhere else.

1079. (*Dr. Thorpe.*) What particular studies of secular change were you thinking of?—I was thinking of secular changes in the properties of springs, in magnetic apparatus, and in various co-efficients of various kinds.

1080. (*Mr. Rücker.*) In co-emicients of elasticity?—In co-efficients of elasticity and in thermal co-efficients; they alter with time, no doubt; but we know nothing whatever about their long period changes.

1081. (*Dr. Thorpe.*) Do you think there is any immediate practical necessity for that knowledge?—Immediate practical necessity? If we had it it would be very valuable, but it cannot be immediately used, because it will take half a century, and possibly more, to accumulate it.

1082. I mean is it known that that kind of knowledge would be immediately valuable; is it known, or is it a mere hypothetical idea?—It certainly would be immediately valuable, because we do not know at present for how many years we can rely upon existing data being themselves accurate; we do not know how soon they may change.

1083. (*Mr. Rücker.*) The whole question of the durability of structures is involved, is it not?—Yes; not only the durability of structures, but the durability of the functions of an apparatus, so far as it depends upon properties that may change with time.

1084. (*Sir Courtenay Boyle.*) You have told us, and I am sure there is not one member of the Committee who will not agree with you, that it would be desirable in some way or other that there should be a body able to test and—I should like to drop the word "standardise" and to say "calibrate," if that is a proper word, in order to distinguish from "standardise"—to calibrate instruments, and also to determine many kinds of physical constants; would it be better in your opinion that that body should be a carefully selected body independent of, but supported and aided by, the State, or that it should be a State Department?—I do not think there is much to choose, because you are not likely to turn out your officials when there is a change of government. If political considerations of that kind came in, I should certainly prefer the independent body.

1085. (*Mr. Rücker.*) Would you consider that a governing body nominated, we will say, by the Royal Society and by some of the great technical institutes, and helped by the State, would be a better governing body than a State Department?—Yes, in view of the fact of possible Parliamentary pressure put from day to day by members of Parliament.

1086. You say that in view of all the facts of the case?—Yes, so far as there might be any conflicting Parliamentary pressure, it would be preferable that the institution should be independent.

1087. (*Dr. Thorpe.*) Is such an institution more likely to be affected by Parliamentary pressure than the Royal Observatory?—No.

Wednesday, 1st December 1897.

PRESENT:

Mr. A. W. RÜCKER, D.SC., F.R.S. (in the Chair).

SIR COURTENAY BOYLE, K.C.B.
SIR ANDREW NOBLE, K.C.B., F.R.S.
SIR JOHN WOLFE BARRY, K.C.B., F.R.S.
Mr. W. C. ROBERTS-AUSTEN, C.B., F.R.S
Mr. ROBERT CHALMERS.
Mr. ALEXANDER SIEMENS.
Dr. T. E. THORPE, F.R.S.

Mr. L. BLAIKIE, *Secretary.*

The Right Honorable LORD KELVIN, G.C.V.O., F.R.S., called; and Examined.

Right Hon. Lord Kelvin, G.C.V.O., F.R.S.

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1088. (*Mr. Rücker.*) I think you have given a good deal of attention to the question of the establishment of a National Physical Laboratory?—Yes.

1089. You were also one of the Committee that was engaged in establishing the Board of Trade Electrical Testing Laboratory?—Yes.

1090. I may say that the reference to this Committee is, in the first place, that we are "to consider and report upon the desirability of establishing a National Physical Laboratory for the testing and verification of instruments for physical investigation"; and we should like to know from you whether you think there is any work of this kind that is not at present satisfactorily done, which such a laboratory could do?—Yes, I think there is a great deal of work that is even at present of practical importance, and is likely to be more and more so, which cannot be done in the standardising and verifying laboratories already in existence.

1091. Could you give us an example?—The standardising for self-induction and mutual-induction of coils, and, again, the testing of electrostatic condensers.

1092. Is that work of a kind that is not at present done at the Board of Trade Laboratory?—It is not at present done at the Board of Trade Laboratory. The Board of Trade Laboratory would be perfectly competent to do that kind of work in practice if it was once furnished with standards, and also with definite instructions as to the mode of using the standards and making the comparisons.

1093. But you do not think that it is in a position actually to prepare the standards for the purpose without additional scientific help?—I do not say without additional scientific help, but I would say, without going away from what it is possible for it to do with its present means and appliances.

1094. You think that it requires a scientific institution to supplement the work of the Board of Trade by providing such standards?—Yes, and methods.

1095. With regard to the measurement of pressure, steam pressure, and so on, is there work of that sort that requires to be done?—I believe there is not any institution under statutory powers, or within the sphere of action of the Board of Trade, by which steam gauges can be tested.

1096. Is that true also in respect to the pressure of condensed gases?—Yes, and that is an exceedingly important matter, I may say, vitally important.

1097. Such, for instance, as the case of condensed oxygen?—Yes, and even the case of condensed carbonic acid and the use of cylinders for carrying condensed gas for illuminating purposes in railway trains and many other appliances. Condensed carbonic acid is used in refrigerating apparatus, and condensed oxygen is largely used, far and wide, over the whole country, at scientific establishments, centres of scientific instruction, and in popular expositions over the whole country, soirées, and lectures, and even entertainments in which photographic reproductions of what has been seen in the course of travels, and so on, are shown to the multitude. Cylinders of condensed

oxygen are carried about in railway carriages and in all sorts of conveyances, to those places of instruction and amusement and entertainment. There ought, I think, to be a definite means of testing the pressure, and ascertaining that, as far as possible, the strength of the material and the pressure to which it is subjected, are proportioned within safe limits.

1098. We have had a great deal of evidence about thermometry, and I do not know that that point need be expanded much, but I should like to know whether you think that the comparison of thermometers in England is at present satisfactory?—In three respects it is not satisfactory. One is as regards minute accuracy between the freezing and the boiling points. The Kew standard thermometer is a mercury and glass thermometer, and thermometers sent to be compared at Kew are verified according to it, but for many purposes it is desirable to know especially in the middle of the scale about 50° centigrade, how far the Kew standard differs from the standard of the hydrogen thermometer, or from the ideal, perfect gas thermometer. Kew I understand, because I had occasion to make enquiry on the subject myself three years ago, has not the means of directly saying what is the error—or, rather, I will not call it error, but the discrepancy between the Kew standard and the hydrogen and nitrogen gas standard in the middle of the scale from 0° to 100°. That is one important point in respect to the scientific use of thermometers. At present I do not know of any practical application to the ordinary affairs of life, or to engineering, in which the degree of accuracy to which I now refer is required, but it is not satisfactory that there should be an uncertainty amounting to two-tenths of a degree centigrade in what the meaning of the Kew standard is. When I inquired on the subject I was informed that comparison with the gas standard at the Bureau International was the only means open to Kew for giving that degree of accuracy which they now require in their thermometry. I think there should be in this country independent means of telling what the practical standards given out to the public mean, to as close a degree of accuracy as it is possible without scientific methods of a high class to read the scale. Anyone can read the scale of a centigrade thermometer to the fifth of a degree without any intermediate graduation; the thermometers verified at Kew have many of them their scale divided to tenths of a degree, but there is an uncertainty to one or two scale divisions as to what is the meaning of the thermometry indicated by a thermometer thus verified and standardised and certified at Kew. That is not satisfactory, although for mere practical applications I do not say that at present there is any important uncertainty. Then there are the low temperatures and the high temperatures. For temperatures approaching the liquefying point of nitrogen at atmospheric pressure, the nitrogen gas thermometer fails utterly. The hydrogen gas thermometer might be pushed lower, but you want investigation there. The only way of measuring low temperatures at present is either the thermo-electric method, or the electric resistance method. Each of those has been used, I believe, for very low temperatures. Professor Dewar, I believe, uses the thermo-electric method for the very low temperatures, but some prefer the resistance method, although I do not think they are right in this. But whether the thermo-electric or the resistance method is used, the only comparison that is open to Professor Dewar himself, and others experimenting in that line, is the prolongation of a curve. Now all engineers and scientific men know that to prolong a curve far beyond the range within which the points have been settled by observation is exceedingly unsatisfactory. It is a makeshift. It is important for estimates to know whether it is 100, or 200, or 50, or 10 degrees, for instance; you may learn something in that way, but it is very unsatisfactory. What one wants is something more accurate; accurate thermometry at low temperatures has become largely a practical want, now that we have refrigerating engines on board almost every ocean ship.

1099. (*Sir Courtenay Boyle.*) Can you enable us to put on the Notes what you mean by low temperature in terms of Fahrenheit or centigrade, merely for the non-scientific readers?—I mean temperatures below zero Fahrenheit, let us say, 10, or 20, or 30 degrees below zero Fahrenheit down to the freezing point of mercury, which, if I remember right, is minus 38 degrees centigrade.

1100. (*Sir Andrew Noble.*) It is the same in the Fahrenheit scale and in the centigrade scale, is it not?—The temperature of freezing mercury is about the same number of degrees minus in the centigrade scale as in the Fahrenheit scale. We have tolerably satisfactory thermometry from the freezing point of mercury upwards, but we want comparisons with the air thermometer at these low temperatures. Below that the ordinary air thermometer begins to fail, and it is a subject of most difficult scientific investigation, the results of which would be of extreme practical importance, to push thermometry down by comparing different gas thermometers, hydrogen gas, nitrogen gas and oxygen gas thermometers at the very low temperatures, and ultimately by deducing—even from the hydrogen thermometer when it begins to fail—by the thermodynamic law, the absolute temperature. That is all within the limits of scientific experimenting, assisted by mathematical theory, but no private individual could undertake it. The results would be of very great practical importance.

1101. (*Mr. Rücker.*) The third point which you mentioned was that of high temperatures?—Quite similar remarks apply to high temperatures. We have air thermometry to about a thousand degrees centigrade—I think that is it—by means of Deville's porcelain bulb. Above that we have no air thermometry. Then there is a question about the air thermometry itself. We have had a great deal lately coming out about dissociation, not merely of chemically combined substances such as the hydrogen and oxygen constituting vapour of water—steam, that is—but about the dissociation of the gases themselves. We believe that the oxygen molecule is double; that it is composed of two atoms, O_2. It is not known at what temperature, if any, the molecule of oxygen gas O_2 splits into atoms. The same may be said of hydrogen and nitrogen. Now, a comparison of hydrogen, oxygen, and nitrogen gas thermometers up to 2,000 degrees centigrade I believe could be made; there are great difficulties about material, but I believe it could be made, and I believe if made it would answer, or go towards answering, the highly important chemical scientific question of dissociation. That would be, *apropos* of the business of this investigation, a bye product; but the main product would be founding accurate thermometry for practical purposes. Now practical purposes are full of temperatures up to 2,000°, but we cannot measure securely, within 200 degrees, temperatures up to 2,000 degrees centigrade. I am afraid what I have just said may be denied by my friend, Professor Roberts-Austen, who is sitting beside me. He has made at my request some measurements of the fusing points of felspar, mica, and quartz. He has given me the results with probable errors. One of them shows 1,520 degrees with an error plus or minus of thirty degrees. A probable error of thirty degrees centigrade seems very large to the lay mind, if I may make use of such an expression, but to the scientific mind, on the other hand, it is marvellously close if we are sure of it to thirty degrees at this high temperature. But we are not sure even of that, because it is founded on a prolongation from 1,000° up to 1,500° of the temperature, as measured by Deville's air thermometer, with very infusible highly burnt biscuit of porcelain.

1102. (*Sir Courtenay Boyle.*) Are these very high temperatures reached in actual transactions?—They go far above them in electric furnaces.

1103. In the manufacture of steel and iron, for instance?—Yes; and in respect to the materials used, such as fireclay; it would be a most important practical investigation to find substances that will take up the running of a furnace above the temperature at which the best fireclay hitherto made melts. There are many substances in nature that have not been investigated that may come into practical use. You want to know more and more of the bearings of all materials used in trade and engineering at exceedingly high temperatures.

1104. (*Mr. Rücker.*) May I put two questions to you in reference to thermometry: Generally, do you think that the extension of the thermometric scale, both up and down, and increased accuracy in it, is of immediate practical importance, and will be of greater practical importance in the future?—Yes, more and more so, especially now when we have alumina dissolved in cryolite and decomposed electrically, when we have calcium carbide prepared by high temperature by the electrical arc, and when we have carborundum. We have all those compounds made, but we do not know the temperatures at which those actions take place. It is, therefore, certain that the Arts will be actually helped by accurate thermometry in the case of electrical furnaces.

1105. May I ask your reasons for thinking it is especially the kind of work that should be carried on in a National Physical Laboratory?—No private individual could undertake it, and it is of vast commercial importance.

1106. (*Sir Courtenay Boyle.*) Why could no private individual undertake it; because it wants more than one mind?—Because of the material expense and the occupation of time. Some wealthy amateur of science might

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chance voluntarily to undertake some work towards that, but the most powerful and the most wealthy amateur of science that has ever been could only do a small part of it, and although we are most grateful to wealthy amateurs of science for what they have done—and a great deal of English science is owing to them—we must not fold our hands and wait till they give results which are of great practical good.

1107. (*Mr. Rücker.*) To pass to another question: do you think the question of the relation between electro-static and electro-magnetic units is a matter which requires investigation, and which is of practical importance?—Yes, it is of great practical importance for the standardising of practical volt meters which are now going up to 11,000 volts for the transmission of electric energy. We are within ½ per cent., I believe, in the reckoning of electric pressure at those high voltages, but practically speaking, we can only measure those voltages by electro-static instruments, and in order to put the electro-static and the electro-magnetic instruments into definite practical connection, we need to know the number of electro-static units in the electro-magnetic unit. We use it now as being 300,000 kilometres per second, but we do not know that for certain within one-third per cent., and we ought to know it to within one-tenth per cent.

1108. Then, again, the measurement of the magnetic field is very fundamental to all electrical and magnetic measurements, is it not?—Yes, it is very important.

1109. And there is at present a good deal of difficulty in even measuring the intensity of the earth's magnetic field?—Yes, there is.

1110. The instruments differ in themselves?—Yes. There is not the same advance in accuracy in that part of scientific work as there has been in some other parts that are more immediately under the influence of practical requirements. We have not, I think, yet got to 1-20 per cent. in the determination, in absolute measure of the three components of the force; we ought to get within that degree of accuracy and instruments for obtaining it are a very great practical want.

1111. Measurements of this kind, I think you will agree, can only be caried out in places which are absolutely free from all electric and magnetic disturbances?—Yes.

1112. Therefore a laboratory, such as is proposed, should be in that respect alone situated at a proper place for conducting such observations?—Yes; it must be out of town.

1113. And also it is work which could be carried on by officials of such an observatory, do you think?—I think it is, certainly.

1114. Another point which had been referred to us is "the systematic determination of physical constants and numerical data"; have you any remarks to make upon that point as to questions which might usefully be undertaken?—Physical constants and numerical quantities expressed in properties of matter would be a very proper subject for such a National Laboratory as that which is now under consideration. The properties of matter which in engineering establishments are tested on the finished piece, large or small, depend upon the properties of the substance used, and there is a great deal of information of practical value for the mechanical engineer and for the electrical engineer, which could be obtained by elaborate experiments on comparatively small portions of the material subjected to tests which would be impracticable in an engineering establishment.

1115. Then you do not think that this work would necessarily require a large engineering laboratory?—No, I do not think that the proposed National Laboratory should interfere with the kind of work that is done in university engineering laboratories or in engineering testing places, such as Kircaldy's. The science that underlies the tests made in these establishments is a subject for investigation which could only be carried on by such means as it is proposed to now allot for the work of a physical laboratory.

1116. Could experiments with regard to the alteration of the properties of bodies when they are subjected to vibration or alternating forces be carried on satisfactorily on the small scale you have indicated?—Yes, such experiments as experiments on the vibration of a watch spring which will perform 50 times 31½ times three million of vibrations without showing any signs of weakening or of altering either stiffness or tendency to break—I mean the hair spring of a watch that will go for fifty years, making three semi-vibrations per second for the 31½ million seconds in the year.

1117. Do you think the observations would be useful to the engineer as well as to the watchmaker?—Yes. Some experiments reported by Sir Benjamin Baker to the British Association in Edinburgh a good many years ago seemed to show weakening after a few million—a very small number of million—vibrations of a bar tested in a certain way. Now, there is a question for a National Physical Laboratory: How far will a number of applications of the stress and removals of the stress alter the material? When the stress lies within such narrow limits as the stress to which the hair spring of a watch is exposed, it does not seem that any number of millions of applications and removals of the stress will impair the material; yet we have the whole question before us of the alleged crystalline condition induced in the axles or railway wheels by running for a certain number of thousands of miles. We want to put that in relation with other properties of matter, and to get some definite knowledge on the subject. A National Physical Laboratory could do that with great ease by appliances which could keep two different springs, let us say of as nearly as possible the same quality, each bending and unbending once a second for year after year, one of them through a certain range, the other through double or triple that range. Then we could get towards something like an answer to the question of the permanent effect on solid material of application and reversal and annulment of strain repeated a great many times. The fatigue of the elasticity of torsion by long continued vibrations is a subject that I have made some slight experiments upon myself. I make such experiments as may be done in a teaching laboratory, which cannot be persevered in for a very long time, but which, if continued, would probe to the bottom a difficult question regarding the properties of matter. Such experiments can be made with great ease in a laboratory arranged for the purpose, and would give information of exceedingly great practical importance, indeed I may say of vitally great practical importance.

1118. May I ask whether the question of galvanic actions which go on between metals in contact is one of practical importance just now?—It is of very great importance. There is at present much want of knowledge as to the cause of the breaking off of steel propellers near the collar between the ship and the sea. I do not know exactly what the latest information of engineers there is, but still there are occasional breakings of screw shafts which it is difficult to explain, but which are attributed by many to galvanic action. Questions of that kind could be examined, and the properties of the matter concerned could be investigated very usefully in a physical laboratory.

1119. To turn next to the question of the constitution of the laboratory if established; do you think there ought to be a highly paid scientific man of eminence at the head of it?—Yes, I think there should be a scientific man of the first class. We do not estimate the value of scientific attainments in money, but we do estimate the value of the work that we can get from scientific men in that way. You must give a salary that will secure the highest class man; that will attract a man from any professorship in the United Kingdom, if money will attract him at all—perhaps I should scarcely put it that way, I will say that can reasonably be expected to bring a man from any of the best professional positions in the United Kingdom.

1120. Would he want the help of several competent assistants?—Yes; and I think really that £1,200 a year is the least that should be thought of for the salary of the chief of such an institution, who is to give his whole time to the work, and not to undertake any other kind of paying work.

1121. Can you draw any distinction between the work which this laboratory would do and that of the Board of Trade Laboratory, with which you have had a great deal to do?—Yes. I think a laboratory of this kind would be an exceedingly useful support and advising element for the standardising laboratories and practical verifying laboratories under the Board of Trade. I use the word "laboratories" just now; I mean not only the Weights and Measures Department and the Electrical Department, but more. I think there must be electrical laboratories, such as that of the Board of Trade, in different centres in the United Kingdom. I think it will be necessary to look forward to having verifying laboratories in Manchester, Glasgow, and Belfast, and possibly in Dundee also—in various places where electric lighting measuring instruments are in constant use. It will be found that to send them up to London to be verified at the Board of Trade Laboratory will be too troublesome and too costly for all concerned. We must get those instruments verified nearer home. I look forward to maintaining the present institution in London, with whatever extension and improvement is necessary for verifying electrical measuring instruments, and to the multiplication of such institutions

to be, as far as possible, ultimately self-paying by the fees taken.

1122. Do you think it is desirable that there should be any direct connection between the proposed National Physical Laboratory and the Board of Trade Laboratories?—Yes, I think the proposed laboratory would be the head and brains of the whole affair.

1123. And that there should be some official connection between them, if possible?—Yes, perhaps there should be an official advisory superintendence, and on the other hand there should be an official answer given to questions submitted to the head laboratory by the practical standardising laboratories. A question may occur which cannot be answered by the means and appliances available in the London standardising laboratory, but the chief of the London practical standardising laboratory would naturally be in frequent communication with the proposed National Physical Laboratory, and would put such questions when they occur.

1124. Do you think he should have an official right to do that?—Yes, he should have an official right to put questions. At present every scientific man in the country would be glad, if asked, to do anything he could do to help Major Cardew; and it is certain, of course, that Major Cardew feels that if this National Physical Laboratory were established under a scientific committee, he would naturally wish to go and to get help, when wanted, from such a committee. For instance, there is the very question of air condensers to which I have referred; Major Cardew could not be expected to establish a trustworthy standard air condenser, and to begin to use it. The measurement of practical electro-static condensers is a thing that must be wanted, and the chief of the practical laboratory would need to ask for a standard. Mr. Glazebrook could give him a standard, but even Mr. Glazebrook I should think would want something more before he could say this is a standard accurate to one-tenth per cent.

1125. Would you be in favour of the governing body of the new National Physical Laboratory visiting the Board of Trade Laboratories in the same way that the Greenwich visitors do the Greenwich Observatory?—I think that would be a very proper, convenient, and useful arrangement.

1126. (*Sir Courtenay Boyle.*) Your evidence seems to show that you think it is desirable that instruments should be verified?—Yes.

1127. Does that mean a limited number of the highest class instruments used by men capable of conducting physical research, or does it mean every instrument which any manufacturer may choose to send?—I think it should only mean instruments for special scientific purposes, or for special manufacturing purposes requiring a greater degree of accuracy than is at all wanted for the ordinary standardising of practical instruments.

1128. How would it be possible to exclude the ordinary sender, say, of a thermometer? What would be the grounds for saying this thermometer is sent to me for mere commercial use, and, therefore, I decline to verify it, and the other thermometer is sent to me for physical investigation, and, therefore, I will verify it?—That question is already answered at Kew. A thermometer will be sent to Kew, the ordinary Kew certificate will be given, and correspondence passes. All practical thermometers are sent to Kew at present, so there does not need to be any change in that respect.

1129. But the Kew people, if I understand it rightly, will examine the behaviour of any thermometer that is sent by any manufacturer?—Yes.

1130. If a State Department undertook to do that, it would have to be an enormous department, would it not?—In thermometry?

1131. If we did it for thermometry we should have to do it for the instruments in other branches, too?—I think the answer would be: Send it to the place that is competent to do it—a practical laboratory. Then, if by special application, it is something more than can be done in the town standardising laboratories, it would be a matter for arrangement; probably, if it is an expensive process, the person who wants it, or the manufacturer, would be quite ready to pay the extra expense if it is for a scientific object. Probably a great deal of trouble would be taken, without making a charge, by the National Physical Laboratory.

1132. Do you think the State should undertake to test the behaviour of instruments used in everyday commerce, or only the behaviour of instruments used for high scientific objects?—On the same principle as it tests weights and measures, the State should test measuring instruments of a certain specified kind.

1133. That leads me to another question. Under the present system of weights and measures what the State does is to test the primary standards; the testing of instruments used for commerce is put into the hands of the local authorities, and is paid for by the people who use the instruments. Would you endeavour to aim at that distinction as regards the other instruments?—I am not sufficiently versed in the distinction between local authority and central authority. I think there should be, under State authority, delegated, it may be, to local authority, the means of testing ordinary practical volt meters and current meters for users of electric light and of electric energy in any part of the United Kingdom.

1134. But whether it should be a State Department or whether it should be paid for locally, you do not distinguish?—No; I think on the whole the persons getting the benefit of it should pay fees which would make it nearly self-sustaining.

1135. Would you make it self-sustaining in that respect?—I would make it as nearly as may be self-sustaining.

1136. As regards the physical constants, if a State Department undertook to determine physical constants, would it not have an enormous amount of work to do; would it not be asked to determine an enormous number of physical constants?—No, I think not; I think there would be no difficulty of that kind.

1137. Would not the electrical resistances of all sorts of metals and of manufactured articles come within the function of the department—say, the resistance of vulcanite?—All such questions might occur; the number of such questions is practically infinite, but there is no practical difficulty in confining the investigation to cases of practical importance.

1138. You think there would be no difficulty?—I think not.

1139. When it is a State Department, mind?—I think not.

1140. And when everybody thinks that he has a demand upon the State, and that he has got a right to call for State assistance?—I would not give that right at all. I would not give a right to everybody to demand an investigation in this National Physical Laboratory. There should be a right by rule for the practical standardising and verifying establishments to demand help from the National Physical Laboratory, but no prescriptive right for anyone else.

1141. Then, as regards the officer to be put at the head of this Department, do you think it would be possible to find anyone, except, perhaps, in one direction, who had sufficient knowledge of all the sciences?—Yes, some of the high-class physicists, professors, or others.

1142. Would their knowledge be sufficiently general?—Yes.

1143. You could find a man of sufficiently general knowledge?—Yes; I think there are many of them.

1144. You think you could find many?—I cannot say how many; I know a very considerable number, any one of whom, I think, would be quite competent to take full charge. What is required above all is a man who, although he is not a person of universal knowledge in every branch of physical science—because, if he were, his knowledge would not be very great in any one—a man who has judgment enough to know what he knows, and to sympathise with others, and to be able to supplement his own want of knowledge by correspondence with others and so on. A high-class man, who would do that would never be at a loss. A great many could be found.

1145. There would be no danger of such an individual pursuing the objects with which he was most associated?—I think not at all in such a position as this, where the duties would be so definite and so obvious. There would be no chance of a high-class man using that position to merely push out investigations in which he himself is interested. There would not be an opening for it, there would not be a temptation for it. Besides that, the class of man that you would put in there would not yield to any such temptation, but would do his duty.

1146. You were good enough to give us an estimate of what should be paid to the head man; but I imagine you have not at all framed any estimate of what the whole laboratory would cost?—I have not.

1147. Not even roughly?—No; I could not state it in my own mind.

1148. But you think we might as far as possible enable it to charge fees which would make it something approaching to self-supporting?—I think the regular charging of fees should be rather confined to the town verifying institutions. Kew already exists, and charges fees, and it has done so well that I should not at all interfere with

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its work, but, rather, would support it, and allow it to extend. I do not think it would be advisable to begin with any intimation that instruments could be sent direct to the National Physical Laboratory, and fees paid for their testing.

1149. You would make the sender pay for the verification or examination of individual instruments, and you would leave the State to pay for the standardisation of the high-class instruments; is that the distinction?—Yes, I think so; I think that would be fair.

1150. You think that distinction may be drawn?—Yes, I do.

1151. The verification or testing of the behaviour of ordinary instruments in commercial use should be paid for by those who wish them tested?—Yes.

1152. But it is the function of the State to test the behaviour and develope the construction of the higher-classed instruments?—Certainly; to develope the construction and occasionally test the behaviour.

1153. (*Sir Andrew Noble.*) You referred to the testing of cylinders, which would be, I suppose, rather a large affair; you would probably have the tests of those gas cylinders that are coming into so much use now, carried out in the large manufacturing centres?—Yes.

1154. Because, to have them all sent up to London would mean great delay and inconvenience to the commercial community?—Yes. But there the National Physical Laboratory would be of great value, because it would lay down the principle of the tests; there would be tests practically made there for the purpose of working out a system of testing; but the instruments to be tested for commercial use should not be sent, in my opinion, to the National Physical Laboratory, but should be sent to an establishment such as you refer to in the local centres of industry.

1155. And, of course, the cost of that one way or another would come on the public?—Yes.

1156. Not on the State?—No.

1157. Then, with regard to commercial purposes and the investigations that private persons could hardly carry out, you yourself have alluded to the effects, I think, both of stresses and of vibrations upon materials; it is of great importance to manufacturers in the country to have such tests carried out by the highest ability the country can produce, is it not?—Yes, it is.

1158. For example, the effect of secular stress upon material?—Yes, and of applications and removals of stress, both simple stretching, bending, and torsion.

1159. Then there is another point upon which I fancy we are ignorant to a very large extent, which is what we call the elastic limit?—Yes, that is so.

1160. Very few important experiments of great difficulty have been made upon the variations in the elastic limit under the effect of stress?—Yes, and under the effect of temperature.

1161. Each of these would be a proper subject for the National Laboratory that we are discussing, and would be of immense value to the country?—It would.

1162. For instance, you yourself alluded to the effect of vibrations in producing crystallization of iron or steel?—Yes.

1163. You are, of course, aware, as everybody who has large experience is, that sometimes you find a crane chain, for example, breaking without very much apparent cause under the test it has been subjected to?—Yes.

1164. For that reason periodically, as you are no doubt aware, these chains are annealed to remove the effects of vibration?—Yes. Besides what I spoke of, I might add brass and other metals. There is the influence of the atmosphere upon brass. A coil of brass, when hung on a nail, is sometimes found as brittle as pipeclay after a few months or years; something of that is known, but not nearly enough.

1165. The point I want to draw from you is that these investigations are much wanted, and will be of much value to the country?—That is so.

1166. Following Sir Courtenay Boyle's remark upon the person who would be Director, or Director-in-Chief of the National Physical Laboratory, I think everyone would agree that he must be a man such as you have described, but it would be, I think, a great advantage, and I would like to draw your opinion upon the subject, that there should be, what you may call, a visiting committee, which should have the power of directing certain experiments to be made?—Yes, I think so.

1167. And to give advice, because, as you yourself have said, there is no man who can have universal knowledge without that knowledge being not very profound?—Yes.

1168. Therefore it would be a great advantage to have a committee so appointed by the Royal Society which should include men the most distinguished in various branches of science, and who would occasionally give directions as to certain investigations they want made?—Yes, and who could consult with the chief in order to add their knowledge to the knowledge of the chief in respect of the work.

1169. (*Sir John Walter Barry.*) I want to ask you whether such a physicial laboratory as you have described would touch the question of the alloys of various metals, and of the behaviour of alloys under various stresses producing molecular change?—It would.

1170. I suppose that again would be a matter of very great importance?—Of great importance.

1171. Not merely as a scientific enquiry, but as having a practical bearing on the trade and manufacture of the country?—Yes. Again, another very important matter is the temperature of expansion, that is, the expansivity with temperature. We heard from Professor Roberts-Austen, in Toronto, of the nullity of expansion of a certain definite alloy of iron and nickel discovered by Guillaume, of France. Something is known of that, and it is a very important practical discovery, but pushing far investigations upon that point and upon various other analogous points in such a national laboratory, would be of great importance.

1172. I suppose you would agree that many things which, at first sight, seem merely scientific inquiries, rapidly assume great commercial importance?—Yes.

1173. And it is in that view, I think, that you consider the State might be asked to pay for many of these investigations in relation to which no fees could reasonably be charged?—Yes, certainly.

1174. Have you formed any opinion as to the locality which would be suitable for such a physical laboratory as you have described?—It ought to be in a place where there is no possible chance of invasion by either an ordinary railway or an electric railway.

1175. I think you know Kew very well?—Yes.

1176. Would Kew be suitable do you think, or is it too near to the railway?—I think Kew would be very suitable; I do not know quite the distances, but I believe that Kew is at a safe distance from any present or prospective railway.

1177. The National Laboratory ought to be in such a position that it is not reasonably probable that any electric railway or ordinary railway would be brought within a certain distance of it?—Yes.

1178. That distance, I suppose, could be laid down?—Yes. The National Laboratory and Kew might be one establishment, and probably would be one establishment with advantage; but the building of the new laboratory would need to be at a sufficient distance from Kew, not to disturb the magnetic observations of the Kew Magnetic Observatory. If the new building is to be contiguous to the present building of Kew, the magnetic instruments would need to be taken to a distance from it, to a hut or to an underground place, perhaps at a distance of a quarter of a mile, or some such distance, from the present place.

1179. I suppose, subject to such requirements as that, there would be some advantage in a reasonable amount of concentration?—Yes. It seems to me that it might be very well to make it actually contiguous with the present building and to take the terrestrial magnetic instruments and observatory of Kew away to a comparatively small place built for the purpose, which could be sunk under the ground, or covered over with twenty feet of earth, so as to make it as good as if it was under ground.

1180. I gather that you think that a laboratory of this sort should be instituted and kept up in such a way that it should have a great reputation for accuracy and should be a standard not only for this country, but for all other countries?—Yes.

1181. That it should be a very high standard laboratory?—Yes, I think so, so that the Germans, for instance, or the French, or people from America, might apply to it for information. I do not see why we should not be able to give as good information on all points and, perhaps, better information on some points, than the Reichsanstalt. The Reichsanstalt does splendid work, but I do not see why we should not do quite as good, and there might be things in which we could do what the Reichsanstalt has not done, or we might do better something that the Reichsanstalt has done well.

1182. You think that if this country does it at all it should do it thoroughly well?—Yes.

1183. And that, *pace* the Treasury, we should not look too narrowly to economy in the matter?—I think economy is a very important thing, but only such economy as is consistent with securing good results.

1184. It is of that importance to this country that it will justify us in looking at it in a large way?—I think it would justify any expenditure whatever that it requires.

1185. (*Mr. Roberts-Austen.*) In reference to those experiments that you mentioned, conducted by Sir Benjamin Baker, in connection with the Forth Bridge?—They were not experiments in connection with the Forth Bridge, they were some experiments made in Germany upon which he reported.

1186. He did make some experiments of his own, and I thought you were referring to those?—I do not know of them.

1187. The Board of Trade has recently appointed a committee to investigate the question of the cause of the failure of steel rails, and several experimenters are working in that direction; is that the kind of work that should be undertaken by such a laboratory as we are discussing?—Yes. I think work of that kind might be undertaken with great advantage.

1188. Would it be easy to distinguish such work from ordinary testing work as conducted in such laboratories as Kirkcaldy's?—Yes, quite.

1189. (*Mr. Chalmers.*) A previous witness spoke of the kind of research which might be conducted at the laboratory in contemplation as being the drudgery of research, would that strike you as a limitation proper to be put on the researches of this laboratory?—I do not think it should be limited to the drudgery, but I think that the person who undertakes such a post must be a person who will not shirk what other people call drudgery.

1190. Would you say that in order not to trench on the ordinary sphere of research, investigation into the physical constants would be the line on which this laboratory in particular should expend its energies?—Yes. I think this laboratory, at all events at present, should not be devoted to mere pioneering experimental work, such as Faraday's, for instance, which might lead to great discoveries. I think that should be left to universities and individuals. If experiments leading to new discoveries come in the proper course of the work of this laboratory, I do not think they should be avoided, but the proper work of this laboratory should be that which is set forth in the conditions under which the inquiry is being made.

1191. You spoke of a director, and you spoke, I understood, of a visiting committee—that commended itself to you, did it?—Yes.

1192. Was I right in gathering that you thought that visiting committee should be practically a committee of the Royal Society, but not altogether so?—With additions from the Royal Society of Edinburgh, and from Irish institutions, the Royal Academy, and so on, and perhaps the British Association could help; but it should be under the auspices of the Royal Society of London.

1193. Do you think that there would be any practical good in a State Department having any control beyond that exercised by the Royal Society through this committee or the director?—No, I scarcely think so. I think that control delegated in this way to a responsible body like the Royal Society of London would be as satisfactory in the public interests as any mode of control that I can think of.

1194. (*Sir John Wolfe Barry.*) With regard to any visiting committee, would you think it advisable that trade and manufactures should find representatives on such a committee?—I should think so, through the London Chamber of Commerce, and, perhaps, the Chambers of Commerce of the chief places.

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1195. Would you leave the selection of the committee to the Royal Society, but stating that the representatives need not necessarily be members of the Royal Society?—(*Mr. Chalmers.*) May I supplement that question before you answer it: You will remember the Meteorological Council and the attitude taken towards them by the Government of the day, asking the Royal Society to appoint a council, which it did, not exclusively from its own members; would your reply to Sir John Wolfe Barry be that you would take a similar line in this case?—Yes, a similar line to that which was taken with respect to the Meteorological Council.

1196. But you would leave the selection of the committee to the Royal Society?—Yes, it should be a selection of persons not necessarily Fellows of the Royal Society of London or of any of the scientific bodies.

1197. So that the large trading interests and manufactures of this country could, if the Royal Society considered it right, be represented on such a committee?—Yes, I think that would be better than giving a rule according to which Chambers of Commerce should be asked to send representatives, as that might be inconvenient. I think that giving the Royal Society latitude to use its judgment in the appointment of this Committee would produce a better result than anything else that could be devised.

1198. (*Mr. Siemens.*) Would it not be better still if the Royal Society were told to appoint in its own discretion certain members of the engineering societies, perhaps outside its own body, and that they must appoint a few representing trade and industry?—I believe that would be very proper.

1199. (*Dr. Thorpe.*) Are you familiar with the constitution and working of the Reichsanstalt at Charlottenburg?—Only from what I have heard chiefly from Sir Douglas Galton, but also to some degree from general knowledge. I have not myself personal knowledge of it.

1200. Is your knowledge, however, sufficient to enable you to advise the Committee how far the model of the Reichsanstalt might be usefully followed in the administrative details of this projected National Physical Laboratory?—I do not know about the administrative details, but I think I should not commence with too great a building at once. I think the proper way of beginning would be a building which could readily grow by addition and addition, of more and more when more and more is needed, but I would not make too great a building or too great an affair at the first start.

1201. (*Sir Andrew Noble.*) *Festina lente*, in fact?—Yes, I would look forward to more and more demands upon the Treasury for more and more expenditure from time to time, according to the public needs demonstrated.

1202. (*Sir John Wolfe Barry.*) Then you ought to have an ample site?—Yes, that is the one thing that should be ample to begin with. From all my recollections of Kew I believe it will be sufficiently ample in respect of site.

Mr. Robert H. Scott, F.R.S., called; and Examined.

Mr. R. H. Scott.

1203. (*Mr. Rücker.*) You are, I think, secretary of the Meteorological Council?—Yes, I am.

1204. And the Meteorological Council is a body which controls the use of a great number of instruments for scientific investigations?—It is.

1205. You are interested, therefore, in the question of the standardising of those instruments?—Yes, I think we are very much so.

1206. Where is the standardising of the instruments you use done at present?—At the Kew Observatory.

1207. Have you found it important to have an institution of that sort to support you in that work?—That was found important when the work was first introduced by Admiral FitzRoy in 1854. The Board of Trade then, finding that instruments, imperfectly constructed *and* imperfectly finished, were extensively in use in the merchant service, requested that certain instruments fitted for use at sea should be devised, and this work was done through the then Kew Committee of the British Association, with Mr. Gassiot as chairman; and Mr. Welsh, who was the superintendent of Kew at that time, actually made one or two sea voyages with those instruments—short voyages to the Bay of Biscay and elsewhere—to see whether those instruments were really suited for use under the conditions which ships at sea are exposed to.

1208. What instruments were those?—Barometers and thermometers; the particular thing was the barometer which Adie, the instrument maker, devised—the Kew pattern barometer, which is now very extensively used.

1209. Have you formed any opinion as to whether it is desirable that the work of standardising, which is at present done at Kew, should be extended?—As far as the Meteorological Office is concerned it is not required that it should be further extended, except in one small particular, which is that the facilities for testing anemometers at Kew are not good. There are trees in the park, and to put up an anemometer in a park inland, with trees, is quite useless. They never feel any violent wind at Kew. The comparison between the wind felt at Kew and the wind felt, say, at Scilly shows that there is a total difference between the two things.

1210. If that were done somewhere else your wants would be fairly well met?—It could also, we presume, be done by establishing rotating apparatus at Kew on the grounds belonging to the Observatory, but that does not exist at the present moment.

1211. Then speaking more particularly from the point of view of your interest in science generally, have you formed any opinion as to the establishment of a national laboratory?—I have considered that it would be exceed-

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ingly desirable that the work of the laboratory should be more extensive than it is at present. A demand occasionally comes in for standardising electrical apparatus, and this cannot be attempted at Kew under the present circumstances because of the existence of continuous magnetic observations at the Observatory; the space available is too small.

1212. I should, perhaps, have brought this fact out; you are a member of the Kew Committee, are you not?—Yes, I am.

1213. Therefore, you are perfectly conversant with the fact that demands are made upon the Committee, which it is not at present enabled to meet?—Certainly.

1214. There is one other point which I think we should like your opinion upon with regard to the government of the new laboratory. If it is founded, the method of management of the Meteorological Council might possibly serve as a precedent; therefore, would you inform us what the relations of the Meteorological Council to the government of the Royal Society are?—The members of the Meteorological Council are nominated by the President and Council of the Royal Society; these nominations are submitted to the Treasury, and the Secretary of the Treasury has in every case written to say that my lords have approved and have appointed these men. A further relation of the office to the Royal Society simply consists in the fact that the report of the office is made to the President and Council of the Royal Society, and forwarded by the President and Council of the Royal Society to the Treasury for presentation to Parliament.

1215. The funds which are at your disposal are paid directly to the Meteorological Council, are they not?—Yes.

1216. They do not come through the Royal Society?—Not in any way.

1217. (*Sir Courtenay Boyle.*) They are paid by the Treasury?—They are paid directly by the Treasury.

1218. (*Mr. Rücker.*) The Royal Society has no right, I believe, to interfere in the management of the Meteorological Council once the members have been appointed?—It has no right at all, except in so far as they presumably might have the right to return the report, saying they were not satisfied with the report, or not satisfied with the work.

1219. You regard the handing in of the report as giving a general right of criticism to the Royal Society?—Certainly. That was, I believe, the object of Lord Lingen in putting in this stipulation that there should be a right of criticism, which right has during these twenty years never once been exercised.

1220. But taking the assumed case?—There is the power.

1221. In such a case, do you think the Royal Society would have the right to report to the Treasury if it was dissatisfied?—I presume they would certainly. I should say that the only direct, so to speak, criticism on the expenditure of the office is that exercised by the Exchequer and Audit Department, as naturally should be the case. They do exercise criticism and send a man once a year, to look over our books, and make any criticisms they think fit. Nothing serious has yet been noticed, only one or two small things.

1222. Do you regard the Meteorological Council as founded for the sake of scientific investigation only or as founded for practical purposes?—It is founded for both. The first inception of the Meteorological Department of the Board of Trade was purely for practical purposes.

1223. Those being?—The supply of instruments to ships and completing charts like Maury's charts, and the whole of the weather work grew out of that, by Admiral FitzRoy's own motion, without any special authority from the Government.

1224. Would you just tell us the practical uses to which they are put, and the work done?—The issue of storm warnings and the issue of forecasts, and then in connection with medical and agricultural purposes, the preparation of a weekly weather report, which shows the total amount of sunshine, rain, and accumulated temperature for each week since the beginning of January every year. The idea of accumulated temperature arises from the idea of the late Professor de Candolle at Geneva that each plant requires a certain amount of heat to bring it to its maturity. Maize requires more than wheat, wheat requires more than barley, barley more than oats, and so on, and in order to obtain that temperature you must neglect every degree below about forty, for the plant is dormant for about eight or ten degrees above the freezing point, and there is no effective growth below forty. Sir Richard Strachey devised a plan by which day degrees of temperature could be calculated, and this is all described in the weekly Weather Report: these day degrees expressed in what is called accumulated heat. The Committee will easily see that, because it is notorious that if it is a cold summer the harvest is late, and if it is a warm summer the harvest is early, the proper amount of temperature for the ripening of the corn having come in a shorter space of time. There is one point with reference to the verification of instruments I should like to mention. That is whether the mark which is put at the Kew Observatory on thermometers could be a registered mark or not. There was a good deal of correspondence carried on, which I have in my hand here, some years ago about this question, and the result was stated in a letter, which I hold, dated 1879, just eighteen years ago: "As the trade mark has not been used prior to the date of the Act to register trade marks (3rd August, 1875), it will be classed as a new mark. The Registrar, we are informed, has an objection to passing monograms as new trade marks, and he rarely registers such a trade mark without an order from the Court to do so." The Kew Committee were informed that it would cost them £70 or £80 to obtain such an order, and they decided to go no further in the matter. The only instruments for which any mark of this kind is likely to be forged would be thermometers and Admiralty telescopes. One case has been proved of a firm who had sent a thermometer to be verified and broken it, they made another thermometer of the same number, and forged the mark. I believe, sir, you were actually present when that thermometer was broken at Kew; it was discovered some time ago. They only found one particular case where a workman had scratched K. O. to correspond with the number of the certificate. There is no suspicion of any extensive forgery going on at all, but there is nothing registered, and nothing can be.

1225. Apart from the question of expense, you think it desirable that such registration should take place?—If it could be done, but I believe it does not come under the Act, being simply a monogram.

1226. (*Sir Courtenay Boyle.*) Was the man who put the K. O. on the thermometer punished for forging the mark?—No, he was not punished. The thermometer was called in and broken, but there were no legal proceedings about it.

1227. Have there been any legal proceedings in protection of the mark?—None at all; it is not a trade mark, and there is no such power.

1228. (*Sir John Wolfe Barry.*) There cannot be any such proceedings?—There cannot be.

1229. (*Sir Courtenay Boyle.*) At the present moment there would be nothing to prevent anybody putting K. O. on a thermometer?—Nothing in the least.

1230. (*Sir Andrew Noble.*) But they would not have your certificate if they forged the mark?—No, they would not.

1231. And a certificate is always sent with a thermometer that you verify?—Yes.

1232. You have described what you are doing at present. Do you think it desirable to have any extension? Do you consider, for instance, that it is of importance that your thermometers should be brought into relation with the gas thermometers?—That question has repeatedly been raised at the International Meteorological Committee, of which I am secretary, which has declared that all thermometers in every country should be referred to the gas thermometer. I, as the representative for England, have always taken the position that, as we are not likely to have temperatures more than about thirty or so degrees Fahrenheit below the freezing point, the comparison with the gas thermometer is not required by our climate.

1233. But if you had the misfortune to take your thermometers into other climates, how then?—We do not do so, except for arctic expeditions. We have no station in Canada, and, in fact, we have no stations outside the British Islands, except so far as regards ships.

1234. I got a thermometer from you many years ago for Canada?—Yes, I remember. At present there are no means of doing anything except comparing the thermometers, by means of solid carbonic acid, with a standard at the freezing point of mercury, but not with the gas thermometer. We have no gas or air thermometer.

1235. You have got one scale, taking the centigrade merely for simplicity, between the freezing and the boiling points of water, and you have another scale between the freezing points of mercury and water, have you not?—We have. I am not myself practically quite familiar with the manipulation of those instruments. My connection with Kew has been mainly managing the whole concern. I managed it for some years as secretary, but not the details of the thermometer verification, which is a delicate kind of work.

1236. Still, you consider it of importance that the thermometers of—I will take three countries—England, Germany, and France—should be in accordance?—Certainly; that is very important.

1237. But they are not?—They are not referred to the same standard.

1238. In Germany they are corrected by the gas thermometer, and in France also, if I am not mistaken?—The Kew Committee are at present busily engaged on that subject, on their own motion. There is a gentleman at present at the Institution at Sèvres, connecting the English standards with the French.

1239. (*Sir John Wolfe Barry.*) I think you said that you did not see any particular direction in which your investigations could be extended, even if there were a National Physical Laboratory?—Not those of the Meteorological Office.

1240. I was going to ask you whether you would consider it a part of the Meteorological Office's business to find out the pressure of wind?—It is certainly part of our work, and we have been carrying out various experiments on that through Mr. W. H. Dines, at the expense of the Office.

1241. At present, is there any real information as to the pressure of wind on surfaces of varying area?—No.

1242. Absolutely none?—Absolutely none.

1243. Does it occur to you that that is a very important question as affecting structures, the sizes of sails, and other matters of that sort?—It is extremely important, but we do not see how the thing is to be carried out.

1244. You mean how experiments could be carried out?—Yes. Only yesterday I was watching a sky sign. No two letters of the sky sign were moved by the wind to the same angle and in the same direction. It is perfectly certain it does not come as a gush of wind that would take in a large area like the front of that chimney breast at once; there would be very little thin streams, varying along different lines.

1245. I do not know whether you are aware that under the regulations of the Board of Trade, bridges and structures have to be made adequate to a pressure of 56 lbs. on the square foot for wind pressure?—Yes; I am aware of that fact.

1246. I do not know whether you have ever considered the question of how much money is being wasted at this time in consequence of that regulation?—I think that my evidence about it to the Tay Bridge Committee would show the view which I took at that time.

1247. I have not had the pleasure of reading that?—It was constructed for standing 10 lbs. per square foot for the whole length.

1248. I do not mean to say that the Tay Bridge was strong enough. I am not saying that for a moment; but at the present time, if one has to design a large structure, we are absolutely without data as to what wind pressure is to be expected upon it, having relation to the area exposed; is that not so?—I believe that is perfectly true.

1249. Does it not seem to you a matter of very great national importance for determination, and would it not fall within the Meteorological Society's scope of operations, supposing they had the money?—Excuse me; you have mentioned the Meteorological Society for the first time. The Meteorological Office is a totally different body.

1250. I meant the body which you represent?—I am representing here the Meteorological Society, but I am secretary of the Meteorological Office. To carry out those experiments on really extensive areas would be a very expensive concern. An attempt of that kind was made in connection with the Forth Bridge. There, speaking roughly, one pressure plate was made to represent the side of a railway carriage, which, I suppose, would be something like ten or fifteen feet high and perhaps thirty or forty feet long, a large thing—and there was a small instrument placed beside it: As far as I remember, Sir Benjamin Baker's experiments did not show very much accordance between the two instruments, so that you could not reason from the small one to the large one at all.

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1251. As a matter of fact, as the area increased the unit of pressure fell off?—Yes.

1252. Very considerably?—Yes.

1253. That is a kind of investigation, is it not, which could only be reasonably undertaken by some public department on account of the difficulties and the expense, and the fact that at first sight it would not have any immediate result?—Yes. The office is at present carrying out a series of observations on pressure at Holyhead by means of a new apparatus devised by Mr. Dines, which does not depend on the compression of springs or on lifting weights in the same way as Osler's instruments did—a plate was driven back against springs, and these springs altered their elasticity with time, and there were various questions about it. Dines' measurement is done simply by making the pressure elongate a spring. The record is not continuous; the maximum pressure reached is marked by a ratchet. This particular instrument, having been tried in London, is now put up at Holyhead and working there. That would give what the maximum pressure in each gale would be on an area of a foot in diameter.

Addendum. [In addition Mr. Dines has another instrument measuring wind force by pressure on a surface of water. This is also working at Holyhead and elsewhere.]

1254. Which, I think you will agree, is very illusory for large structures?—We cannot reason from it.

1255. Do you not think that it would be a subject of very great importance for thorough elucidation?—It would be an exceedingly important question for that; the only question is whether one is at all likely, with any reasonable amount of money, to obtain any result.

1256. Sir Benjamin Baker at any rate did something at the Forth Bridge with his limited means?—Yes, he did something.

1257. He determined to some extent that the question of area was a largely modifying question. About the Trade Mark of the Kew Observatory, have the Committee so little money that they could not pay the £70 to get the mark registered?—They did not consider it was worth the £70.

1257A. The matter was not really urgent?—They did not consider that it was urgent.

1258. Did you say that it could be authorised by the Court at an expense of £70?—No, but that it would cost that to bring it before the Court.

1259. Then you might spend the £70 and not get your registration?—That is quite possible. I would venture to hand in what may perhaps be of interest to the Committee, my own history of Kew Observatory, which goes down to the year 1884, and contains the entire history of Kew from the very beginning up to that date, and how everything was developed. It is mentioned in the Year Book of the Royal Society, but the detailed account is here, and I also hand in a complete file of the reports of the Kew Observatory since the year 1884. I have brought also a copy of the last report of the Meteorological Office.

Mr. W. Ellis, F.R.S., (who had been present during the examination of the previous witness) called; and Examined.

Mr. W. Ellis.

1260. (*Mr. Rücker.*) You were for many years head of the Magnetic Department of Greenwich, I think?—Yes, for about twenty years.

1261. You have also taken a great deal of interest in meteorological work?—Yes, both in magnetism and in meteorology.

1262. You have come across the question of standardising both in relation to magnetics and to your other work?—Yes.

1263. Have you formed any opinion as to whether or no it is desirable that the present opportunities for standardising should be increased?—I certainly think they should, because in those two directions the work has been of great benefit. The testing of magnetic instruments at Kew has been of benefit to magnetic observatories over the whole world, and the testing of meteorological instruments has been likewise very beneficial in the United Kingdom as making it possible to receive meteorological observations made with instruments which could be depended upon.

1264. How has the magnetic work at Kew been useful to the world?—As I understand, Kew Observatory is applied to from all directions for magnetic instruments, or has been in past times when required, and the instruments that are furnished are first tested at Kew, and the values of their different constants determined before they are sent away.

1265. That is a work of importance, is it not?—That is a work of importance, I should say.

1266. In the Meteorological Society you have a number of amateur meteorologists, I suppose?—Yes.

1267. Gentlemen who are interested in the thing?—Yes, they voluntarily undertake observations, and these gentlemen get instruments that have been tested at Kew.

1268. And speaking for the Society they have found that to be important and useful?—Certainly.

1269. Are there any cases in which you think the work requires extension or does Kew meet all existing requirements in that particular respect?—As regards meteorological observations Kew meets all practical requirements.

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The testing of thermometers is of course such as is necessary and is quite sufficient for meteorological purposes. Of course a physical inquiry is another matter.

1270. Have you given any attention to the question of the establishment of a National Physical Laboratory?—The want of some institution such as that proposed can hardly be said to be new. My experience leads me to think that a National Physical Laboratory would be a desirable establishment. Perhaps I may illustrate: In past times the work that might possibly have been usefully done at such an institution depended for its performance so much on individual or voluntary endeavour, and so progressed less rapidly than it otherwise might have done. To take an instance: in 1834 the national standards of length and weight were destroyed in the fire that took place in the Houses of Parliament. Two Commissions were appointed, one to report on the matter, and a second one to construct new standards. The consequent work was a very heavy one, for in addition to the restoration of standards, there was also the question of the making of thermometers, for there were no reliable standard thermometers at that time available. I had the privilege of giving in various ways some little assistance in this work, which was not completed, nor copies of the new standards distributed to foreign countries—for a great many were made and distributed to foreign countries—until 1856; that was twenty-two years after the fire at the Houses of Parliament. Probably if such an institution as is proposed had been in existence the work would have been completed in a much shorter time. I remember another small circumstance. In 1859 there was a certain Sale of Gas Act passed by Parliament; it was suddenly found that that involved the preparation of various standards of measure, and the Astronomer Royal at Greenwich was called upon suddenly to assist in this work; I remember it took a great deal of his time when he was very busily occupied. That would be a work that would fall to such an institution as is proposed, I should imagine.

1271. Those particular cases would be met now probably to a certain extent by the Board of Trade Standards Departments?—Probably so. The construction of the standards of length and weight, under the second Commission spoken of, was undertaken by members of the Commission—Mr. Francis Baily, the Rev. R. Sheepshanks, and Professor Miller.

1272. At the request of the Government?—They all undertook the work at the request of the Government. There was a Commission sitting at the time of which Sir George Airy was chairman. Sometimes it becomes desirable to undertake matters that are mainly of scientific interest. For instance, in the year 1837 the Government granted £500 for the repetition of the Cavendish experiment. That work was undertaken by Mr. Francis Baily. Things of such nature arise which, possibly, in an institution of the kind proposed might form subsidiary work. Mr. Scott has spoken of the various other matters.

1273. Is there any particular in which you wish to add to what he said?—No, I think not.

1274. We thought that if you and Mr. Scott were present here together his evidence might probably cover the ground?—Mr. Scott has been questioned about the pressure of the wind and has said all that is necessary about it.

Mr. R. E. Crompton.

Mr. ROOKES E. CROMPTON, called; and Examined.

1275. (*Mr. Rücker.*) You have been engaged in electrical engineering work for many years?—Yes, I have.

1276. You have been engaged in it both technically and scientifically?—Yes.

1277. You have served on the Council of the Institution of Electrical Engineers?—Yes.

1278. Of which body you are a past president?—Yes.

1279. You have carried on research work in connection with your electrical engineering, I think?—Yes; from time to time in the business of electrical engineering we have to try new materials, and we have to inquire into the nature of those materials and find out what those properties are. For that purpose we found it was necessary to keep a laboratory quite apart from the works to which one could give one's time and quiet, generally in the evening; and that has been carried on for the last 10 or 12 years in London.

1280. You yourself have given a great deal of personal attention to it, have you not?—Yes. We keep a staff there; I think we have 9 in the laboratory altogether; a head, 4 chief assistants, and 3 general assistants. We carry on the examination of materials, the testing of materials, and the standardising of certain instruments—not the manufacture of instruments, but the final adjustment and standardising of instruments in comparison with our own standards, which we have done our best from time to time to verify by comparison with other standards.

1281. You confine yourself to work there which is directly important to you in your business?—Yes.

1282. Do you think that English engineers are at any disadvantage as compared with foreign engineers in regard to the facilities which they have for standardising their instruments?—It touches us this way; supposing a dispute arises as to the correctness of a standard, our only chance of comparing is with certain ohms at Cambridge or at the Board of Trade Laboratory in Richmond Terrace; but up to the present we have not had the chance of comparing the standards which are of great commercial importance, such as the sub-multiples of the ohm—the hundredth, the thousandth, and the ten-thousandth—simply because such standards do not exist in this country. I believe Major Cardew has recently added one, but we have not been able to compare with it up to the present time. Such standards do exist in the Reichsanstalt at Charlottenburg, and we have been able to get complete and correct check comparisons with them. We have had to be at the expense of sending over to them for that purpose. As regards standards of electro-motive force, the same thing applies. In order to make the usual commercial measurements that are common in central station testing rooms, or in County Council testing rooms we require standards of electro-motive force as well as standards of resistance. As is well known to you, the usual method of measuring is by measuring the fall of potential taken over a standard resistance, and that fall of potential has to be compared with a standard of electro-motive force, which is usually the Clark cell. We have supplied a very large proportion of the generating stations, both Municipal and Company stations, in the kingdom with such apparatus, and the question from time to time arises as to the correctness of the standards we have supplied. It is a very laborious thing for us to compare a thousandth of an ohm with an ohm at the Cavendish at Cambridge, and, as I say, we have not had any chance up to the present of making comparisons in Major Cardew's laboratory. I believe on account of Treasury reasons, there being no scale of fees fixed until quite recently, so that the Board of Trade could not undertake comparisons for us. The only thing we could do was either to purchase standards from the Reichsanstalt, or, which is the more common thing, to send our standards over to them to compare for us, and that is costly.

1283. To take the work of your own laboratory first, could you give us some of the principal investigations you have there carried out for the purposes of your business—take the potentiometer, for instance?—The evolution of the potentiometer, which was first suggested to me by Dr. Fleming about 12 years ago, has been carried out in our place. I do not refer to the potentiometer itself as a simple instrument, because its principal use, as a means of comparing P. D. or E. M. F. is, of course, based on the accuracy of the standards we employ for comparison; and so really the main of our work has been in the perfecting of these standards. The potentiometer by itself has stood still for a good many years, as we got it to a sufficiently advanced state several years ago; but the calibration of the standards themselves and the investigation of the properties and the permanency of the materials of which the standards should be composed have formed a very large share of the work of our laboratory.

1284. Have you paid any attention to the question of thermometry?—Might I just go further on with what I was saying? At an early date in the calibration commercial standard work, it was evident that we must eliminate as far as possible the question of the temperature co-efficient, and the invention of Manganin, which is an alloy that pretended to do this, was a matter which at once attracted attention. Immediately Manganin was invented, Krupp and various others brought out alloys which pretended also to have low temperature co-efficients; some of them proved to be well founded, some of them to be not so well founded. It has really taken several years to observe Manganin, and the other alloys offered, properly to see whether they really were constant. Manganin was not in certain forms; certain forms in which it was sent out by the German manufacturers were very disappointing, and led to the abandonment of Manganin; in other cases we

got excellent results. We had then to find out what was the difference between these two classes of Manganin. It seemed a very easy thing to do this, but it has taken several years to get fairly accurate data; the result has been that Manganin has been rehabilitated, and we have got it used everywhere, especially for the heavy standards. It has turned out to be a very satisfactory material. But we should never have got to our point if it had not been that the Reichsanstalt were doing the same work at the same time, and their results have agreed with ours to such an extent that we saw we need not go any further. We were quite satisfied—when a great public institution like that had obtained the same results that we, in our humble way, had got in a private laboratory—that we were not justified in spending further money on it. Consequently we have benefited directly in that particular matter. You asked about pyrometry. Of course, it is on the same lines. Everything depends on the constancy of the thermal co-efficient of the metal that you employ. Callendar worked so hard on platinum, and did such good work on platinum, that we took it up at an advanced point; but I do not think we appreciated the effect of the very wide divergence of the co-efficient of platinum over various ingots, all of which professed to be pure metal. The result has been that we have never been able to make any batch of thermometers from platinum as a metal, or from any specification of platinum. We have been obliged to have specimens drawn from one ingot, and have made a complete range of tests of those specimens, and then have brought the whole of that ingot into the form of wire, taken additional check tests, and made our thermometers with one co-efficient of rise from that batch from that ingot.

1285. (*Mr. Roberts-Austen.*) You are speaking now of resistance pyrometers, and not of thermo-junctions?—That is so; I have had no experience of thermo-junctions.

1286. (*Mr. Rücker.*) These thermometric questions are of importance to you, from the point of view of measuring the temperature in various parts of electrical machinery when in action?—Yes. Of course, we manufacturers have to make transformers of various kinds, and we have also to use iron for the cores of armatures of motors and dynamos. One method of testing the loss is by the rise in temperature of a certain mass of metal, and this rise requires to be accurately and rapidly measured. Thermometry, by reason of the mercury thermometers, was a most hopeless business in measuring this rise in a mass of metal—nothing gave you such unsatisfactory and such untruthful results, the lag of the rise of temperature of the mercury itself being so great. We are now able to make platinum thermometers of extremely small mass; a thin sheet of mica, perhaps, one hundred-thousandth of an inch thick, with a ribbon of rolled platinum wound round it, can be inserted between the sheets of a transformer, and you can thus get the temperature rise in place with extreme accuracy. I think that has revolutionised our knowledge of the rise of temperature inside electrical apparatus.

1287. Then it is not too much to say that the very accurate measurement of temperature has of late years acquired very great additional importance, from the point of view of the electrical mechanician?—Yes; it is far the most accurate method for testing the efficiency of electrical apparatus, from a workshop point of view.

1288. With regard to the ageing of standards, have you any remarks to make on that point?—Simply from commercial reasons, we cannot age them by sheer age, as it were. We have to imitate the ageing by various modes of annealing. Once we have determined the proper methods to be adopted, the matter is at an end; but you have actually to age a certain number of specimens and compare them with the artificially aged specimens carried out by means of annealing at different rates. That has been one of the things which has taken time, and we have been fairly successful with it.

1289. Then a number of different physical properties have also been examined by you, I think?—One branch of our business has been electrical heating apparatus, and it has opened out an entirely new field of inquiry—that is, the behaviour of insulating materials at very high temperatures. Most people think that china is china and glass is glass, and that at all temperatures its electrical resistance is the same. They will be woefully disappointed when they begin to get it up to high temperatures. This change, or, rather, the reduction of the insulating property at high temperatures, is most marked in the case of enamels. As the principle of all electrical heating apparatus has been the use of enamels for attaching the wires to metallic bases, which are intended to be heated, it has been of supreme importance to us to arrive at the best enamels to be used. Long series of tests have been carried out to determine this, extending over three or four years, and we have really had to do for ourselves what the trade will have to do for themselves at some other time. Naturally, we have more or less kept these results to ourselves, as they have been very expensive and costly; but we should have much preferred to have bought the materials to a specification which had been obtained for us in a laboratory where it could have been carried out much better than we could possibly carry it out.

1290. (*Sir John Wolfe Barry.*) And where it would have been open to all the world?—Yes; a trade secret is not worth having.

1291. (*Mr. Rücker.*) Then have you given any attention to the changes of density produced by rolling?—Yes. A great deal of work has been done lately, or attempted to be done, in the production of commercial copper by direct means from crude liquors—that is to say, copper has been deposited in various forms, so that it can be drawn into strip or wire and used direct without re-melting. It behaves in a very peculiar manner. It sometimes is not so dense as it should be, and the results do not come out correctly when tested by measurement per cubic centimetre; we have, therefore, to find out how far it alters by further rolling, wire-drawing, and annealing. This is a very common class of work that we are called upon to do, not so much for ourselves as for others. We get paid a fee for making a test of copper under certain conditions. We say, "As received, its conductivity was so and so, when passed through the rolls it altered to so and so, the change of specific gravity being so much."

1292. Then with regard to the rate of oxidation of bodies subjected to high temperatures?—This, of course, is important in electrical heating apparatus, and I think in any other electrical apparatus; but our attention has been more particularly directed to the electrical heating apparatus. Nickel steel, for instance, of certain proportions, has most remarkable properties in the way of scaling very slightly at high temperatures, and in pyrometry we have found certain proportions of nickel with iron are almost free from scaling, within limits—I will not say absolutely free from scaling—that is to say, supporting wires in the pyrometer will stand fourteen to sixteen days in a flue without practical alteration of electrical resistance; whereas, if we reduce the percentage of the nickel in the alloy, say, four to five per cent., the conditions entirely alter. This has been a very interesting thing, and it has been of great commercial importance, for, naturally, directly we found that this was the case, it opened the whole case, and made electrical soldering irons possible, which had not been possible before, on account of this gradual alteration of resistance.

1293. I think you have something to tell us about the effects of electrical annealing?—Electrical annealing is a very convenient form, not only for the laboratory, but there are many cases in which, by electrical annealing, you can get what you require in the change of physical property either as regards hardness or as regards conductivity, and you can do it, of course, without oxidation, it is so easily carried out in closed vessels.

1294. I understand that you do a great deal of this examining and reporting work for others?—I have given you the staff in our laboratory. It has to be paid for.

1295. Have you made any special study of insulation, both at high temperatures and at ordinary temperatures?—I have given you one case of materials such as enamels; we are called upon to deal with others, as a great many inventions have been carried out lately in medium temperatures—materials to take the place of slate; I think they are sulphides, but I am not chemist enough to say exactly what is the chemical composition of them. Anyhow, they are materials which can be cast into the form of slabs, and used as switch-boards, provided the temperature does not rise above 200 or 250 degrees Fahrenheit. We have had to report on other materials of the same class, but I do not recall them just at this present moment. Slates and marbles, and those materials that we may call of the medium class, we are often being asked to report upon. For instance, people will open a slate quarry, and then they want to know whether their slate quarry will produce slates for switch boards; if it has got metallic veins in it, it is unsuitable.

1296. (*Mr. Roberts-Austen.*) Veins of pyrites, do you mean?—I do not know what they are, but we see that they are metallic veins; and if they follow from hole to hole, you find 400 per cent. reduction in the insulation resistance of the material. With marbles, again, there is the same thing. Then come low temperature materials, including bitumens and pitches.

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1297. (*Mr. Rücker.*) Have you had to pay much attention to the questions of alternate heating and cooling?—In connection with the heating apparatus, certainly; the effect has been that certain materials become so brittle from molecular change that it limits their commercial use; and we have had to eliminate them by simple trial and error.

1298. You have given us a great many examples of the kind of work you are carrying on, which you think desirable; and I should now like you, if you could, to give us some reasons why you think this should be carried on in a National Physical Laboratory?—One reason is this—we have to make a private laboratory self-supporting; we cannot afford to do work for nothing. In practice, we do some work for which we are not paid, but, as a rule, every investigation is carried out just as though it were a job in our own shops. There is a shop order number entered for it, and the man's time is taken on it, and as soon as he has got his results, so that I or my chief assistant can write a report for the man for whom the report is intended, the work stops. There are many cases in which the laboratory is rigged and all ready for certain tests, when, if we spent a few more pounds, we could make a very complete investigation; but we have to drop short very often at a very interesting point, because we cannot afford to carry it on. We often do carry it on, just for the interest of the thing; but there is a great tendency to stop short; in fact, if I am away, the orders are definite to the head of the laboratory that investigations, as a rule, are not to go on beyond the commercial stage of giving an answer to the man; and he chucks it after that point. Of course, that would not be the case in a public laboratory; you would make your investigation so complete that you could tabulate the whole of the properties of the material, etc., and in many cases you would be able to answer, not only the particular questions that were put to you by the man who sent you this material to test or to report upon, but you would be able to get information which would enable you to answer other people's questions without any further tests.

1299. Those other questions being questions of commercial importance?—Yes.

1300. Do you think there would be any risk of the work of such a laboratory being so great that it would be impossible to carry it on at any reasonable cost?—I think there is some risk, and I think that it would be very advisable, in the first instance at all events, to limit the scope of the investigations; but I think it would be quite possible to limit it within reasonable bounds. I think the great fear in a laboratory of this kind is that the work should be spread over too wide an area, and not be well done.

1301. Do you think that it would be an efficient safeguard if there were a strong Committee appointed, perhaps, in the first instance, by the Royal Society, but containing representatives of technology, who would manage the laboratory?—Yes, that is the remedy, but you should have a sufficient number of commercial men on it.

1302. Provided that condition were satisfied, do you think the commercial world would be satisfied with such a body as the Royal Society being empowered to select the members of the Committee?—Personally, I should think so.

1303. Do you think it is essential that there should be at the head of this laboratory a man of very high scientific attainments?—Yes.

1304. Who would probably, however, require very good assistants in several directions?—Yes. Of course, you think of a man at once in your mind. I know of men who have done such work splendidly.

1305. I should also like to ask you whether you think that the establishment of such a laboratory, to put a general question, is really needed by the electrical industry?—Certainly. I think Dr. Fleming and myself played a considerable part in the agitation which got the Board of Trade Laboratory started; and although it has gone a very little way, it has certainly already been of great service. If it had not been for the fact that the Board of Trade Laboratory was in existence, I do not believe that our own standards would have been accepted as they have been accepted all over the country.

1306. Do you think that the work you propose should be done at the National Physical Laboratory could be clearly distinguished from that done by the Board of Trade?—I think it would be better apart from the Board of Trade.

1307. Would you prefer to see it under the management of the Royal Society, for instance, to being under a Government Department?—I would. I think it would be better under the Royal Society than under a Government Department.

1308. Do you think that the work carried out, partly independently in that way, would necessarily clash, or that you could distinguish between the two classes of work that ought to be done in the two places?—I think that the Board of Trade Laboratory, carried on as it has been up to the present time, is utterly inadequate as a standardising laboratory; and I think that, once we had a National Physical Laboratory, the Board of Trade Laboratory would become, as it ought to be, the necessary adjunct to Major Cardew's office as Consulting Engineer to the Board of Trade.

1309. It could not do such work as you propose to be done?—No, unless very large sums were spent upon it.

1310. (*Sir Andrew Noble.*) The investigations that have been carried on in your laboratory have proved of great value to you, I understand?—We simply could not do without them.

1311. But you believe that, on the whole, they would be better done in a physical laboratory, such as is contemplated?—The accuracy would be very much greater, the time given could be very much greater, and as time is a very important element in these things, the results obtained would be better. Then the fact that they would be quite impartial in a national laboratory, whereas in a private place they are always supposed to be slightly tainted with the bias of the chief, I think would add to the value of a National Physical Laboratory.

1312. If so done, you consider that it would be of immense value to the manufacturers of the country at large?—I believe so thoroughly, and I have said so.

1313. You referred just now to the question of the Board of Trade standards, and we have had evidence from other witnesses upon the point; but would this division of labour somewhat meet your view, namely, that the National Physical Laboratory should have the standardising—if I may use the expression—the establishment of the standards, and that when these standards were prepared, and the mode of using them specified by the physical laboratory to the Board of Trade, the mere comparing with others might be done by the Board of Trade, as at present?—Of course, it might be done, and there may be advantages in the double plan. What puzzles me is this: You get out of the commercial world a certain number of fees; now those fees will either go towards reducing the expenses of the physical laboratory, or the expenses of the Board of Trade Laboratory; you will not get two sets of fees out of people.

1314. Certain standardising work, or comparison with standards, is fixed by Statute, is it not?—Yes.

1315. We will have some difficulty in having that altered, and that is why I am asking you this particular question?—That is the sole disadvantage, that I say you will not cheapen the cost of investigation so much as you would otherwise do.

1316. Do not misunderstand me; I do not mean that any investigations are to be undertaken by the Board of Trade; they would rest entirely, as I gather is your view, with the physical laboratory?—Yes.

1317. I mean really that instruments, the accuracy of which have been determined by the physical laboratory, should be transferred to the Board of Trade, with instructions as to the best mode of using them, and then what is determined by statute could be carried on by the Board of Trade?—That would undoubtedly work quite satisfactorily.

1318. Is it your opinion that a large proportion of the work that the physical laboratory would do might be made self-supporting?—I think so.

1319. You have given some illustrations by saying that in some cases you would have liked to have gone further, but in justice to your clients——No, in justice to my own pocket, because I should only be paid a certain fee.

1320. In justice to your own best client, then, you have gone no further, but that a physical laboratory, such as we contemplate, might carry out these investigations, especially if they seemed of importance and likely to be of use to the country at large afterwards?—Yes, I think so.

1321. Therefore, the cost to the country, if you made the laboratory to a very large extent self-supporting, would not be so very great?—I hope not; I think it would not be great.

1322. Also, all these things might be done gradually—you would feel your way?—I think that we have to proceed gradually. I should commence with the preparation of the physical standards required, and take any investigation work as it offered, such investigation work as the plant at the disposal of the laboratory admitted of; then, if work offered constantly for which they had no suitable plant, a strong case would arise for enlarging.

1323. The mode of carrying out the work would be—supposing a good man at the head of it, and you have said that you know, at all events, some who could fill such a position—that the work to be done would be overlooked and specified by the consultative committee that you have discussed?—Yes, certainly.

1324. (*Sir John Wolfe Barry.*) Where is your laboratory?—At my own house; I have got two floors for it.

1325. At Colchester?—No, in London.

1326. Can you give us any idea of the cost of your laboratory?—The amount expended at my laboratory and at the testing department at Chelmsford taken together has reached £4,000.

1327. Have other large works like yours got similar laboratories?—I believe so, but one knows very little of those secrets. Siemens, for instance, I should imagine have; I know that Silvertown have. I believe all the places have, practically. Parsons has, I know, a considerable investigating plant.

1328. You take in work for other people?—Yes, in order to reduce the cost of the investigations made on behalf of our own firm.

1329. Do you take any work from anybody who wishes to have investigations made, assuming you have got facilities for doing it?—Yes.

1330. From anybody?—Yes. We do not actually advertise, but everybody knows that we do investigation work, and certain people send it on to us.

1331. Do you think there is much duplication or repetition of work in these numerous laboratories which have no inter-communication or inter-correspondence?—Yes; I should think probably I do identically the same work that two or three other laboratories have been doing, and that we really compete.

1332. And possibly are doing the same problem?—Yes.

1333. To that extent, if there was a public laboratory, I suppose in comparison there would be a saving of time and labour?—Yes, there would certainly.

1334. Then I suppose also one is right in assuming that the investigations which take place at your laboratory, or at those of others in similar positions, are investigations which have an immediate commercial utility in view?—Yes.

1335. And there is not the same possibility of investigating the properties of new materials, unknown materials, as there would be in a Government laboratory?—That is so. In the first place we have not the physical means of doing it, as we have not got the apparatus for carrying out the whole of the investigation, and in the second place, as we do not get paid for it we cannot afford to do it.

1336. And you stop when the commercial question has been answered?—Yes.

1337. To that extent all investigations in private laboratories are limited in scope?—Yes, I think so.

1338. That is not the case in such an institution as the Berlin Institution?—No. I believe, from what I have seen of the reports of the work on materials carried out at the Reichsanstalt, that they do not rest with just the first question put to them, but they go through the whole gamut and make a more or less complete report on the material or problem put to them.

1339. In the one case the investigation is an exhaustive one, and in the other it is of necessity limited?—That is so.

1340. (*Mr. Roberts-Austen.*) With regard to the magnitude of the industries affected, can you give us any idea of the scale on which such operations might be conducted on something like the basis of the £3,000 or £4,000 that you have already mentioned?—Lately I have gone in for a lot of investigations for the bicycle world, and they are people who are paying pretty readily just at present. For instance, the Americans have introduced nickel steel in construction work, and the whole question of how to deal with it they have kept a secret in America—how the Columbia people, for instance, use it for the framework and for various parts of their bicycles. We have had to find it all out for ourselves, and we charge a fee for doing it. I have been doing this for various firms; and, as they have found out that our electrical laboratories were not such second-rate places after all, they have asked us to carry on other work into which we have introduced electrical means. For instance, we find that the efficiencies of chains for bicycles is a very easy thing to work out with the potentiometer—you get the comparisons of the energy absorbed in the chains very accurately taken. The bicycle people pay us better fees than the electrical gentlemen do. That is one thing which began to occupy the laboratory lately, and I hope will continue to do so.

1341. (*Mr. Chalmers.*) You spoke of £4,000, I think, as your turnover, part of which you got back from fees, and the remainder of course you pay yourself; so that it is worth a considerable sum to you, otherwise you would not keep it on?—It is about £1,000 a year on the wrong side as regards Crompton's. An account of the laboratory expenditure is kept, and about £1,000 a year has to go down to an experimental account in Crompton's.

1342. That is a part of your establishment charges in the way in which you conduct your business?—Yes, our trade expenses are charged with loss on the laboratory of about £1,000—it has been more.

1343. Of course you do not pay fees to yourselves?—No, we debit the trade expenses with the amount.

1344. (*Mr. Roberts-Austen.*) I could go on examining you all the afternoon, but I will content myself by asking you this general question: There is, in fact, a vast field unexplored?—Yes.

1345. Which might be opened up profitably by the kind of institution which is contemplated?—Yes.

1346. Remuneratively?—Yes, I think so.

1347. (*Mr. Chalmers.*) Your test for that, I gather from a previous answer, would be working on the lines of the work that came in; were you, for instance, to have this laboratory to administer yourself it would not be your idea to research at large, but as work came in you would pursue it?—Yes. I would treat it very much as a commercial business, and I should like to see it self-supporting, or nearly self-supporting. Knowing what the Treasury is, I think that we should be more likely to get additional funds for enlarging it or for making it a larger affair, if we showed that it was pretty nearly self-supporting. In the first instance, no doubt, we should do a good deal of pot-boiling—getting in the money as we could.

1348. Following the lines indicated by the work that comes in, you would, would you not, be on lines which would tend to be those on which the commerce of this country required to be helped?—Of course you would. You would take the most crying cases; the tests that are most wanted you would carry out.

1349. (*Mr. Roberts-Austen.*) I will just ask you one question that I have asked a previous witness: The Board of Trade has appointed a Committee to consider the question of the wear of steel rails. Is that the kind of work that you would contemplate?—No, it is not that I was contemplating; I have no experience in such investigations.

1350. Would it be suitable for investigation by such a laboratory?—I think if you go in for that class of work in the first instance you will make it a very large laboratory, and a very expensive one. I should prefer that that came in at a second stage—but that is only my personal view.

1351. (*Dr. Thorpe.*) I should like to ask you, as you are familiar with the working of the Board of Trade Laboratory, whether—inasmuch as the existing Board of Trade Laboratory is in the very strong position of being protected by statute, whether you can see, assuming that this projected laboratory is set up, any necessary incompatibility between the two institutions—whether the new physical laboratory would in any way clash with the existing Board if Trade, and whether their functions would overlap?—I think I was asked a question which would put it perfectly clearly that matters can be so arranged that they need not overlap. The preparation of the original standards is better carried out in a laboratory outside of the London limits, where you have quietude and freedom from vibration, and all that sort of thing; but after those standards are fixed and sent in to the Board of Trade, they can be used as a means of verifying the legal standards, if you may call them so, that people send to the Board of Trade for the purposes of comparison.

1352. Of course, I remembered your answer: my idea, in taking you back to that point, was really to ask you if you would indicate to the Committee what would be the relations between the Board of Trade Laboratory and the projected physical laboratory?—I gave that answer just now because I was led up to it, but still it is an answer which, I think, I should have arrived at myself as a very fair line of demarcation. There is another line, I think, one might suggest, and that is that as the investigations at the Board of Trade Laboratory cannot go beyond a certain point—the nature of the place, the size of the place, its position, the vibration in Parliament Street, the whole of these things together, make it certain that you cannot do work of a certain class there—that work, which the Board of Trade cannot do, must go to another laboratory outside of London.

1353. (*Mr. Roberts-Austen.*) And is done?—And is done in other laboratories, as a matter of fact. They could not hope to prepare standards of any kind with any degree of accuracy at the Board of Trade: they could only go up to a certain point, and that is not a very high point. I can do better myself, and most of us in our private labo-

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ratories are doing better than the Board of Trade—of course, I may be very wrong in saying all this, but we think so in our laboratories. It is a topic of conversation.

1354. (*Mr. Chalmers.*) Would the trade follow them into the country?—No, I think it would be rather a serious matter to have to send a large quantity of instruments far out of London; but I did not mean very far in the country—as far as Kew, for instance, which you know is not a very serious distance.

1355. That would be not too rural?—That would be within reach.

1356. (*Dr. Thorpe.*) What I really want to get at is what should be the relations between the Board of Trade Laboratory and the new laboratory. Should, for example, this Committee, which is talked of as administering the affairs of the new laboratory, have any definite relations to the Board of Trade Laboratory?—It has been suggested—a suggestion in which I heartily agree—that the relation should be that the Board of Trade should not determine standards, but that it should use standards determined for it by the National Physical Laboratory, and that it should use them for purposes of comparison with instruments sent by people who wish to pay the Board of Trade fees to have certain things compared.

1357. Should the Director of the National Physical Laboratory, a gentleman, we are told, who should be of high scientific attainments, have any official relations with the Board of Trade Laboratory?—I think he should not.

1358. He should not?—I do not know; I have not examined the question very carefully yet. I should think it would be better that he be independent of it, for why should he want to refer to the Board of Trade for the preparation of a standard? A standard is a standard; it is a physical fact which he has to determine, and he does not want to be biassed by what the Board of Trade want. So I do not see why he should be in any way under the Board of Trade.

1359. It is not that he should be underneath the Board of Trade, it is the other way round; I mean to ask whether this gentleman of eminent scientific attainments should not be, to some extent, made responsible for the due performance of the work of the Board of Trade Laboratory?—I do not think you can do that.

1360. (*Mr. Rücker.*) Do you think it desirable that the governing body of the National Laboratory should act as a visiting committee to the Board of Trade Laboratory in the same way that the Committee of the Royal Society and of the Royal Astronomical Society act as a visiting committee to the Royal Observatory at Greenwich?—It has never been put to me before, but coming on the spur of the moment it appears to me an eminently good idea; it is my first view, and I daresay it is the right view.

1361. And that the Board of Trade should have an official right to consult this Committee on questions of difficulty?—If they wish to; that is good.

1362. On the other hand, the Committee should have a general visiting power over the Board of Trade Laboratory?—Yes.

1363. That appears to you to be reasonable?—That appears to me to be a good idea.

1364. (*Sir John Wolfe Barry.*) I suppose you would assume that any work done at a Government Physical Laboratory would be open to all the world, and published from time to time for the benefit of large manufacturers and small manufacturers, and, indeed, everybody?—It follows that it must be so.

1365. There would be no private investigations?—No.

1366. If a man took some investigation to be pursued, whatever was found out as the result of that investigation would be public property?—I think so. Of course, it is possible that in the way of making your place pay, it might be arranged that the use of a part of the laboratory should be given to a man for examining into a process by himself, and, of course, he would keep the results to himself under those circumstances; but that is a side issue.

1367. Do you know whether that is done in Berlin; how is that managed in Berlin?—I do not know for certain; I think I have heard of something of the kind, but I do not know enough of it to speak with certainty.

1368. Do you think any private investigation can be pursued under conditions there?—I know they do something of the kind in Liège; a man locks himself up in a room, and has the use of the apparatus, and carries on private investigations, the results of which are not divulged at all. Monsieur Gerard told me so when I was there.

1369. That investigation would have to be made by an individual who was not a servant of the Government?—That is so. He simply has the use of the room under certain conditions.

1370. That would not be an investigation by a paid official of the Government?—No. All such investigations must be made public.

1371. (*Mr. Rücker.*) I should like to press that point, because I think it has been raised for the first time, and it is important. Take such a case as this—a thermometer maker who is trying to improve thermometer glass, and wishes to have it tested. Should he be allowed to send the glass to the National Physical Laboratory, and to receive a private report as to its properties?—You can see that from his point of view it would be very desirable. I do not like to answer straight off the reel, because such a private report clashes with the general idea of a public laboratory.

1372. (*Sir John Wolfe Barry.*) It clashes with the commercial view, you mean?—Yes. I should think you might deal with those kinds of questions by some special means of giving private reports for half completed investigations; as, such a one, as contemplated by Professor Rücker, would be an incomplete investigation. I should think that that question of incompleteness might determine it.

1373. (*Mr. Rücker.*) You think the difficulty might be got over?—I think it might be got over in some way of that kind.

1374. (*Sir John Wolfe Barry.*) But I suppose for the good of the whole trade of the country, apart from the interests of an individual manufacturer, and putting aside the question of the repayment of expenses, it would be better that any investigation made there should be public?—Yes, it would be as a whole, but you have this disadvantage. Professor Rücker's question to me points to this: Suppose a man has got an idea which might lead to patent protection, and he wants an investigation carried out to see whether the material he is using will do certain things; if the line on which he is working is to be made public others will follow it up, and he will lose the fruits of what he has done already. The result is that he will not take it to the laboratory at all, so the laboratory would lose his fee, and it is quite possible the results would never be worked out by anybody, and there is the risk that his invention would be lost to the community. On the other hand, if the investigation at the public laboratory enabled him to complete his patent, at the end of that man's patent the invention, such as it would be, would be thrown open, and so there would be a disadvantage to the community if help from the public laboratory were withheld from him at a certain stage. I think in a difficult case of that kind you might arrange some such thing as I have mentioned, that is, that a report on incomplete investigations might be given up to a certain point privately without publication.

1375. Of course, it is rather a difficult question, and opens up a large view, does it not?—Yes.

1376. Because in the case under consideration you would be using a Government building and Government land for private interests?—Yes, but he would pay for it.

1377. He would?—He might pay an extra fee.

1378. He could pay Messrs. Crompton and Co. for that?—Yes, perhaps he might.

Mr. J. Swinburne.

Mr. JAMES SWINBURNE, called; and Examined.

1379. (*Mr. Rücker.*) You are a member of the Institution of Civil Engineers?—Yes.

1380. You are also a member of the Council of the Institution of Electrical Engineers?—Yes.

1381. And also a member of the Council of the Physical Society?—Yes, that is so.

1382. You are nominated by the Institution of Electrical Engineers to give evidence to-day?—Yes.

1383. Have you given any attention to the question of the desirability of founding a National Physical Laboratory?—I have. I think a National Physical Laboratory would obviously be of benefit to the public if it is of benefit to scientific research, to technical research, or directly to commerce. The whole object of science, if it has an object, is the benefit of the public; the only difference is that the benefit of non-technical scientific research which has no obvious bearing on commerce is more remote; that is to say, it is simply a question of remoteness. The benefit must come if it is a benefit to science; the more abstract the science, the more remote the benefit, but not necessarily the less benefit by any means.

1384. Would you draw any distinction between the class

of work which is chiefly required for the non-technical science, and that class of work which is done by those totally interested in the applications of science to technology?—There is no sharp distinction unless you are dealing with pure research work, then I think there is. If you are not dealing with research work, but dealing with instruments there is no sharp distinction, and one merges into the other.

1385. Have you any reason for thinking that such an institution as this would aid those who are interested in technology in carrying out their work?—It depends very much what the proposal is. I do not really know quite what the proposal is, but almost anything would help more or less indirectly or directly. If it is for pure research work, it depends, of course, on the nature of the research, whether it will come directly into commerce or not. If it is for checking instruments it will become commercially useful, that is to say pecuniarily valuable, if I may put it so, at once, because you cannot imagine any institution for standardizing or rather for checking instruments for purely scientific work that you could not at the same time and with almost the same apparatus use for commercial work.

1386. I will just tell you what the terms of the reference to us are?—I know the terms of the reference; they are a little bit vague.

1387. Do you think there is work which could be done better by a National Physical Laboratory than by individual firms?—Undoubtedly.

1388. For what reasons?—It could be done better because a National Physical Laboratory doing work once for all for everybody would have better appliances, and it is obviously better that important work should be done by one concern once for all, and done thoroughly, than done over and over again in a half-and-half way by private firms or investigators who cannot afford the necessary apparatus to get the right accuracy.

1389. Then you would have this work done for fees, of course?—It depends on the nature of the work. If you are going to do research work I do not see how fees can come in, but the checking of instruments I certainly think ought to be done for fees, otherwise the place would be overwhelmed by people sending instruments who do not really want it. You must charge fees to prevent excessive work coming in. The trade would be glad enough to pay fees; it would pay them well enough to pay fees to get work done that would cost them a great deal more to get done worse by themselves. It is important from the physical laboratory's point of view to get fees, of course, because the more fees they get the more they can do, and the better the thing will be as a whole.

1390. Do you agree that there is a large class of work in the way of testing instruments that would come to this laboratory if established?—Immense.

1391. Could you give us special instances?—In my own particular branch of the profession there are electrical instruments of all sorts, resistance coils, volt meters, and in fact all electrical measuring instruments. In engineering, which is an enormously larger and much more important thing, you would have all the questions about gauges. It must be remembered that accurate measurement has been introduced really by engineers, not by pure science. Accurate measurement in this country was practically introduced by Whitworth, who started upon his own account and fed the country with accurate gauges. He also introduced the standard screw threads which have been taken up everywhere.

1392. To go back to the question of the electrical instruments which you mentioned first, does the Board of Trade Laboratory meet the want which you describe?—I do not quite know what the Board of Trade Laboratory does or what it is supposed to do. The Board of Trade people will generally do anything they can, if it is within their powers, but I do not think yet it meets the want. However, I do not really know what they are empowered to do. I take it that the Board of Trade simply deals with types of meters and of instruments of that sort that directly come in between buyer and seller. You may divide the instruments which are checked into two classes —instruments that directly come in between buyer and seller; and meters and instruments indirectly used in manufacture, such as resistance coils; they are two totally distinct things.

1393. Do you think the work that the Board of Trade has undertaken is a work of a progressive nature—that science is improving our knowledge of such standards, and that the real accuracy required is improving?—I have no doubt the real accuracy required is improving. I do not know how far the Board of Trade affects that. I take it the Board of Trade at present is looked upon as an institution that will not pass meters, and the difficulty is to get a meter sufficiently good to pass the Board of Trade. In that way, of course, the Board of Trade is immensely useful, but I do not think the Board of Trade is the sort of place you would go to to get a resistance coil measured, if you wanted to know what it was. I daresay they would do it, but I am not sure that it would not be simply as a matter of courtesy on their part. I do not know whether they are obliged to test any individual coils you bring in.

1394. I should like you to tell me why you think a National Physical Laboratory would do work of the kind you have been describing better than a private firm; I mean the checking of instruments?—Obviously, they would have better apparatus and they would have an enormously larger number of instruments sent, because if private firms are going to do it, you would have several private firms doing it, and the work would be split up like any other trade concern, and no one private firm would have the right *prestige*. I think the whole business of all the firms put collectively would not be so great as the business of the National Standardising Laboratory.

1395. Do you think English trade would be at a disadvantage as compared with foreign trade if there was not some central institution of this sort where standardisation of this kind was carried on?—Yes; that part of the standardising does not come directly into the question of foreign trade, but it obviously is so; it is a disadvantage to have to spend money on duplicating apparatus all over the country, instead of having it done properly at one central place.

1396. And at a place whose prestige would be recognised abroad?—Yes. Both those points are very important—both the prestige and the accuracy. You would get both of them in that case, and you would get them at much less expense to the country.

1397. Is there any necessity at present for testing screws?—I do not think there is any necessity for testing large screws such as Whitworth's threads, but there may be still a necessity for certifying that they are right, authoritatively. Whitworth is really a private firm, and certainly manufacturers of all kinds of gauges need a place for them to get their gauges certified as right other than on their own authority. Moreover, the metric system is permitted now, but it is most important for this country that the makers be more than merely permitted to use it, and that every facility should be given them to take up the metric system in this country for the sake of our export to our colonies, and to other countries and their colonies. We want to have every facility for getting metric gauges checked, and every facility for, if possible, having the same screw threads adopted in England on the centimetre system as abroad, so that we shall compete on the same grounds as the Germans and French abroad. I think that is of enormous importance. That must be done by some central authority, and it should preferably be done by some body who is kept in touch with foreign Governments, which no private individual can be very well. I think that is essentially work that a laboratory like this might take up.

1398. (*Sir John Wolfe Barry.*) Are there continental standards of screws in the same way that we have the Whitworth standard in England?—I do not know what the position is as regards the continental system. I think they have a continental system of wire gauges on the centimetre system, and I am not sure but I think it is made without very much reference to the difficulties of wire drawing. That is a sort of difficulty that often arises; you want to draw a wire in steps; you do not want to draw in half steps or to take two draws.

1399. Take the screws for the moment; you do not happen to know whether there is a standard in France and another standard in Germany, or whether all the standards are the same?—I do not know; I have not looked it up.

1400. (*Sir Andrew Noble.*) You are referring to the relation of the angle to the thread?—Yes, so that an English nut might fit either a German or a French stud or screw.

1401. (*Mr. Rücker.*) With regard to the introduction of the metric system, do you know how far the powers of the Standards Office of the Board of Trade would meet the requirements of trade in that respect?—I don't know how far, but I do not think so far that even with the English inches people go and get standard gauges checked there. If as an engineer you buy a box of gauges you get them generally from Whitworth; there is no further mark on them, you simply buy them as Whitworth gauges and that is all about it. I do not think

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you would get them checked by the Government in any way.

1402. With regard to other instruments, for instance, steam engine indicators, are those things that require testing?—Obviously, steam engine indicators are very important. I do not know how it is done generally, but enormous sums of money depend, in buying and selling, on the indications of a steam engine indicator. I do not know how those indicators are tested, you simply get an indicator from a good maker, and if the other man does not object to it, it is accepted.

1403. There is no public test of it at present?—Not that I know of.

1404. Do you think it desirable there should be such a test?—Certainly.

1405. Then, again, take micrometers?—I put micrometers under the same heading as the Whitworth gauges I have mentioned.

1406. And true planes?—True planes are another matter altogether, because you are not dependent on anything more than simply a plane there. You are not dependent on a standard. It would be convenient to have planes that you knew were true. Micrometer gauges have been made enormously in America by Browne and Sharpe, and Browne and Sharpe's gauges I think come into this country. If you buy a first-class gauge in this country now you will find it is made by Browne and Sharpe, I think.

1407. With regard to photometry, is there any necessity that more attention should be given to it?—Yes. At present photometry is simply in a chaotic state. A central station engineer will give no end of attention to getting the dynamo within the last one per cent. of efficiency, and he will take lots of trouble over his leads, but the energy will be used in lamps, and people have no idea what sort of light these lamps are giving, and they waste more by not knowing anything about the light than they would if the dynamo had been pouring half its energy through a short circuit. That is really largely due to the standards of light being so bad. There is not very much wrong with photometers as photometers, it is the standards of light that are so bad. Different people set up standards and get totally different results.

1408. Would you wish that question to be undertaken by a central institution?—Certainly, it might be undertaken by some one authoritatively. At present I think the only authorities are the Metropolitan Gas Referees, and I think the gas companies in this country simply assume their standard; I do not know enough about gas companies to speak with certainty, but I do not think there is any legal definition with regard to a provincial gas company unless it is in their particular Act.

1409. Is there any necessity for testing electric cables?—Yes. That is quite another matter apart from what we have been talking about. If a central station engineer buys a cable at present he generally wants it tested under very high pressure, perhaps 20,000 or 40,000 volts, to see if it is all right. The purchasing company has no apparatus for such a test, and very often the selling company has not such apparatus. That is a thing that might very well be done by a laboratory of this sort, simply as a convenient way of making fees, because it is very important to the business to be able to test these things It will be very expensive if each cablemaker is going to put up his own apparatus, because it runs into hundreds of pounds, whereas one apparatus could do all the testing for contracts in the country and really with great reason quite a considerable fee for each test might be charged.

1410. With regard to this and other testing work, do you think it ought to be paid for by fees?—Certainly.

1411. Do you think that such work would be largely self-supporting?—I think it would.

1412. It is obvious that there are a very large number of problems of this sort that might be proposed?—They are infinite, really, I think, the things that are needed, You would have to begin with the ones that are most needed.

1413. Do you think there would be any grave practical difficulty in selecting between those problems which are most urgent and those which might be postponed?—No, I think the demands of the public would show it.

1414. How would you have the choice exerted—by the governing body, I suppose?—By the governing body. I think that the governing body must regard the laboratory as to some extent commercial, and that if it gets a great many applications to do one thing and a few to do another, then unless the thing for which there are the few applications is one which is very important, its importance being guaranteed by a large fee, it is obvious that the others, the numerous applications, are the ones that ought to be attended to.

1415. Supposing that the laboratory made a profit, would you have that go to the Treasury or to furthering the work of the laboratory?—I think it ought to go to further the work of the laboratory in the way of research, and so on. I do not know whether it is a thing I ought to speak upon; it may be perhaps rather political, but I think the Patent Office and the Post Office paying large surplus revenues into the Treasury is a scandalous state of affairs. It is simply taxing people who write letters and taxing people who are good enough to invent. I think that is a thing that ought to be quite the other way. Leaving the Post Office and the Patent Office out, if this laboratory can make money like that it will be making money at the expense of industry, and the whole of that at least ought to be devoted to furthering the more remote benefits of industry by means of scientific research; more than that, I think that it would be quite fair for the Government to supplement any profits that the concern might make and to devote both to research.

1416. Then to take the question of the government of the laboratory, have you thought at all as to what would be the best arrangement?—Yes. I think that depends very much upon what the laboratory is going to do. If the laboratory is going to do work of a purely scientific nature, I think it ought to be in the hands of purely scientific people; if it is going to do work partly or wholly technical, depending that is to say on fees got from outside, and so on, I think the supervision should be partly or wholly technical.

1417. Do you think that the technical world would be satisfied by some such arrangement as that the Royal Society should appoint the governing body, as it appoints for instance the Meteorological Council, but with some condition laid down that the technical world should be largely represented on the committee so appointed?—I do not think they would. I think that if the work is to be largely technical and the utility of the laboratory is to be largely technical it should be controlled largely by people who are appointed as technical people, not by a society that is essentially untechnical. I think, therefore, that if it is going to do work of that sort it should be governed very largely by people appointed by either the Institution of Civil Engineers—which stands in the same relation to technical societies that the Royal Society does to scientific societies—or by people appointed by various societies. Even if they were appointed by the technical societies they might all be Fellows of the Royal Society; but I do not think an institution whose work has to be technical should be governed nominally by a society whose whole object is untechnical.

1418. Have you seen the Reichsanstalt?—Yes, I have just been all over it. It struck me, simply as an engineer, that the work was done very extravagantly. An engineer is a man who looks at things, not only with regard to what they are going to do but with regard to what they cost; and as an engineer it struck me that the Reichsanstalt was managed very expensively. You could tell at once that the people had not to pay for the work out of their own pockets, or it would have been very differently done. That really means in a case of this sort that if work is done extravagantly less work will be done for the money—I am putting all these things from a very commercial point of view, of course; and therefore I think it is important that economy should be observed as far as possible, and I think the only way of observing economy in an institution like that is to have it largely in the hands of people who understand the relation of work to prices.

1419. Do you think that the Reichsanstalt in spite of these defects has been useful to German trade?—I do. I have no doubt it has been useful to German trade, and I should like to see the National Standardising Laboratory infinitely more useful. I might point out that I have given this evidence as being nominated by the Institution of Electrical Engineers, which is a technical society; if I had been nominated by a purely scientific society I would, perhaps, have given evidence more about the purely scientific branch of the work; but I do not want to give any personal views, I want to give, as far as possible, what I conceive to be the view of the society that has nominated me.

1420. (*Sir Andrew Noble.*) You gave some evidence about the metric system; under the permissive Act I imagine you will be able to get from the Board of Trade any measuring instruments tested upon the metric system, because that is the object of the permissive Act, is it not?—I imagine so, but I do not think the Board of Trade lays itself out for checking boxes of gauges, which is more what I mean. I do not mean that you cannot go to the Board of Trade as a final appeal to see that your things are right. But even in inches, if you get a box of gauges such as are ordinarily used in works,

there is no Government mark on them at all. No doubt Whitworth's have been to the Board of Trade and have checked the standards from which they make their gauges.

1421. Whitworth's original standards you mean?—Yes, the originals, and I should doubt very much if Whitworths, even, ever compare their sub-divisions with any sub-divisions at the Board of Trade; I think you will find that they have probably taken the Board of Trade yard.

1422. You can take, for example, a 6-inch Whitworth ring gauge and you can put a 3-inch, 2-inch, or 1-inch into the same gauge, with almost perfect accuracy, which shows how far they will go?—Even that is pretty difficult, because, if they are made absolutely truly, you should not be able to put two cylinders into a ring—I think a great many people would regard even a plug and a ring gauge as not satisfactory, if you could put the plug through the ring gauge at all.

1423. But you must take the one as true and the other as simply a check, because, of course, we are quite ready to admit that there must be some difference of diameter or you could not do it?—Yes, but if the plug will go through the ring I think you may take it that both are wrong, or one is, because, although there is unevenness, it ought to vary both ways, so that if they are both as nearly accurate as possible they ought to jam.

1424. No doubt, they both cannot be absolutely accurate, but they are near to it; but there is a far greater difference than that, and that is in the way in which you use your micrometer?—Yes.

1425. Two different men frequently go a thousandth one way or another from their mode of using the micrometer?—Undoubtedly.

1426. The mode of using it is almost as important as the other?—That is so, undoubtedly.

1427. What I meant in my question to ask you was, that, as far as mere comparisons with the metric standards are concerned, you can or will be able to get that done at the Board of Trade?—Yes, as far as that goes, but really I do not think the average engineer would even go to the Board of Trade, he would probably take the ratio 39·37079 and work to that, as near as he could, or something of that sort. I was looking at it the other day and I found that the ratio of sixteen to sixty-three is very nearly within one in 10,000. An engineer would probably work with something of that sort; he would probably alter his screw cutting lathe if he only had to make one new wheel with a multiple of seven teeth, so as to get a 16 to 63 ratio.

1428. The only other question I have got to ask you is with reference to your views about the Committee of Management, or, I will say, the Supervising Committee. Supposing the main objects of the Physical Laboratory to be to bring the highest scientific ability of the country to the doing according to the terms of reference to this Committee certain things which will be of great benefit to the country at large, and which, at the same time, require the highest scientific knowledge, would not a committee appointed by the Royal Society, which should take due notice of the technical questions to which you have referred and see that manufacturers, if you like to say so, are efficiently represented on the Committee, be sufficient, instead of going to the various subsidiary societies?—I have no doubt, if I may put it so, that the Royal Society would be perfectly competent to run such a laboratory; but I do not think such a laboratory should be run, if it has to be commercially worked, by a society that is constitutionally non-technical and non-commercial, merely because such a society happens to have a certain proportion of its members who, in addition to or in spite of being purely scientific, are also technical.

1429. I think you must have misunderstood Professor Rücker. I think his question was not that they were all to be selected from the Royal Society—the Royal Society was only to be the nominating body?—I did misunderstand him, then.

1430. (*Mr. Rücker.*) What we are anxious to know is whether the representatives of technology would be satisfied with a governing body appointed by the Royal Society on the understanding that the members of that governing body should include representatives of the various departments of industry, and should not necessarily consist of Fellows of the Royal Society alone?—I think they would; I think that would give complete confidence. I see the importance of dealing with one Society and the impossibility, if you begin going from one society to a large number, of knowing where you are going to stop, because there are societies all over the country, and it would be impossible for each one to send a proportion of members. I only wish it to be understood that I do not think the average north country engineer would have much confidence, perhaps wrongly, perhaps rightly, in a national laboratory run entirely by the Royal Society as the Royal Society. I do not think there could be any objection, in fact quite the reverse, to its being run by people nominated by the Royal Society, it being understood that the Royal Society, in so nominating, shall nominate people who are distinguished in technology, whether they are Fellows of the Royal Society or not—most of them would be Fellows in the ordinary course.

1431. (*Sir John Wolfe Barry.*) Have you considered this point at all: that if you have a National Physical Laboratory, which on the demand of anybody makes an investigation and arrives at certain results, as to the properties and behaviours of materials under certain conditons, whether the information so gained should be made public, or whether it should be kept for the benefit of the person who pays the fees?—I have not considered it, but if I may speak without having considered it, I would say that I think that depends entirely on the sort of fee charged. If an institution like this is going to do work of that sort, we will say to investigate something—take it, for instance, that a man wanted a patent——

1432. Assume something in principle—the behaviour of certain alloys, for instance?—If that is to be kept private I think that it could only be done so by charging a very large fee, because otherwise it would be wasting the time of the staff. I think there would be enormous difficulty in it, and that it would really amount almost to swearing the Government to secrecy, because, supposing it was a question of alloys and that an institution like that was making private researches in alloys, it would be certain to come across the same thing later on, and then it would be bound not to publish it, because it had already reported on it at some earlier date. I think, myself, you would have to publish it.

1433. You would have to publish a yearly return, or a half-yearly return of all investigations that had been undertaken?—I think so.

1434. Does it occur to you that such publication would largely affect the commercial returns, and that people who were investigating for the sake of patenting, or anything of that kind, would not then be prepared to pay fees to the National Physical Laboratory, and, therefore, to that extent, any hope of its being self-supporting would be largely modified, if not endangered?—I do not think so, because I do not think the kind of man who is working at something of that sort would come to such an institution, anyhow. Take the case of patenting. I have had a great experience of patentees; they are the most suspicious men on the face of the earth; they would never trust anybody with anything—I do not think even they would trust the Government.

1435. I am not at all averse to your idea that it ought to be published, but I wanted rather to get your mind as to whether, under these circumstances, the amount of work that might be extremely valuable to the whole nation at large would warrant the hope that the institution could be self-supporting?—I do not think you would get very much work of that sort, anyhow. I think the chief amount of work that you would get from the public for which fees would be paid, would be for checking instruments, and measuring things in various sorts. I do not think people would come to you to find out some question about alloys, or any question of that sort. I think there would be very little income from such sources.

1436. Then, really and truly, your view would be that this laboratory should only be for standardising instruments?—I do not think that at all; I think the laboratory should do a great deal of research work. As far as the getting of an income goes, I think it should be done by checking instruments chiefly.

1437. At whose demand would they be doing investigations into the behaviour of alloys, say?—That, I think, would be determined by the Committee. If the Committee is, as proposed, it would have a very good idea of what things were important to the public, and what were not, and it would have to use its own discretion.

1438. In all those matters it could not possibly be self-supporting?—It could not be self-supporting in such things as researches in alloys, at least, I do not think so.

1439. What you mean, I think, is that the standardising of instruments could be made self-supporting?—Yes.

1440. But you confine that hope of self-support to that branch of the laboratory?—Yes, certainly.

1441. I rather took it in a larger way?—I did not put it clearly. I think the checking of instruments ought to be a very much larger thing than the checking merely of philosophical instruments. I want it to cover the checking of every kind of instrument that is wanted in commerce, and I think that might bring a very large income,

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and save an enormous amount of money to the country at the same time, and that it would give a balance which ought to be devoted, plus, I hope, money got directly from the Government, to research work.

1442. But I think you draw the line a little between what you call strictly scientific research work, and research work which seems to have some immediate commercial promise?—I mean to draw a line, for instance, between researches on alloys on the one hand, and researches on the best way of jacketing a compound engine on the other. I do not know whether such a thing as the jacketing of a compound engine would come into any such laboratory, because it is rather a big thing, and it is, no doubt, a departure from the original idea, but it is, of course, physical research. However, there is an instance where it does not pay any one manufacturer to do a thing of that sort, because if he gets it right he has spent a great deal of money, and everybody else can have the results and go on where he left off without having spent the money. Without going to the extreme case of jacketing engines, there are a lot of small things which it does not pay any one person to do, which require to be done.

1443. (*Dr. Thorpe.*) I would just like to ask you what your idea is about the mode of government; you seem to think that the inclusion of the technical element in the board of management is most important?—Yes.

1444. For the reason that it is desirable that the control of the whole organisation should not be vested solely in the hands of the Royal Society?—Yes.

1445. The existing Kew Observatory obtains a very large proportion of its income directly from the trade?—Yes.

1446. And the Kew Observatory, as at present managed, is solely in the hands of the Royal Society?—That is so.

1447. Have you any reason to know that the trade is dissatisfied?—No, but I think you will find that the chief income of the Kew Observatory is in testing thermometers—probably mostly clinical thermometers, and watches.

1448. There are a large number of other things, such as sextants, tested?—There are a large number of other things, undoubtedly; but I think you will find that most of the income is from those two.

1449. It is true that a very large proportion of their income is from these things, but then they still cultivate all sorts of outside commercial relations?—They do. I do not say that the National Laboratory could not work if it were controlled entirely by the Royal Society. I daresay it would; I have no doubt it would; but I think you want to do more than that—you want to work in the best way possible, and you also want to secure the confidence of industrial people.

1450. I am coming to that. Do you not think that you would, to some extent, secure the confidence of commercial people if the commercial element was not, perhaps, so directly represented on the Board of Management?—I do not think that would come in. I do not think it is a question of any trade rivalry between people, because there is no way in which a technical man having some control over such a laboratory could use it for his own benefit against the benefit of other people.

1451. Might it not be apt to give a direction to the kind of research which was taken up, there being such a number of individuals of that kind on it?—I think that is exactly the reason why they should be on, so as to have more influence on the direction taken in research work; that is to say, to get it, as a whole technical, not to get it technical in any particular direction. Of course, I can quite see that engineers might object because the work was becoming chemical, or something of that sort—of course, there is that objection.

1452. My point, rather, is that there is already existing in the Royal Society a sufficiently large body of technologists who might be considered as unbiased by any kind of personal consideration?—Yes, I do not deny that you could get people in the Royal Society to do it, but the Royal Society is not a technological society. Its doors are not open to a man, because he is a good technologist; they are open to him because he is a good scientific man, although he may accidentally be a good technologist also.

1453. Do you not think all those branches of technology, with which this institution will concern itself, are actually represented by leading technologists in the Royal Society at the present time?—I do not know; they may be; I have not looked to see, really. If it is so, it is very fortunate that it is so. But it is not due to the constitution of the Royal Society; it is due to those technologists also having gained a reputation in pure science.

Mr R. K. Gray.

Mr. R. K. GRAY (who had been present during the examination of the previous witness), called; and Examined.

1454. (*Mr. Rücker.*) As we know, through having been unfortunately ill you have not been able to prepare for us a proof of your evidence, so, perhaps, you will kindly make a statement in your own way?—I am not only Engineer in Chief of the Indiarubber, Guttapercha, and Telegraph Works Company, but for the last 10 years, owing to circumstances, I am more the Managing Director than actually the technical man. Still, I know a good many of the technical questions, and from my first training I may be able to be of use to you. We make a great many kinds of electrical instruments and dynamo-electric machines; in fact, altogether in our employment we have about 3,400 work-people of different sorts. We have got an indiarubber manufactory and a great many branches that are really interested in the proposed National Physical Laboratory. From the manufacturers' point of view I say that I, personally, am absolutely in favour of the establishment of such a laboratory. I come from the Institution of Telegraph Engineers, but I do not know exactly the views of my colleagues there, so what I may say may be to a great extent personal information, but I will try as far as I can, in anything you have to ask, to give in answer to your questions what I think are their views on the subject; but still, I suppose my evidence will be more personal than as representing the society.

1455. Still we may take it that you were selected to be a witness as a representative electrician?—Certainly, but without any instructions.

1456. Therefore they probably intended you to give your personal views, which they imagined would be consonant with those of the trade at large?—I expect so.

1457. What particular problems in which you have been especially interested do you think might be referred to the proposed National Physical Laboratory?—In our Instrument Department at Silvertown we require standards from time to time to work to, and those standards of course we submit to the different people that have proper standards. In that connection I am sorry to say that we have always to send over our resistances to Charlottenburg, but our condensers are tested at Cambridge by Mr. Glazebrook—we do not know of any better people to submit them to.

1458. Do you find that the Board of Trade Laboratory meets your wants in that way at all?—Really, what we do is the answer to that question, if you will allow me to say so.

1459. Have you paid any special attention to the ageing of coils?—That is with reference to alloys, probably?

1460. Yes?—I asked one of our staff, who had been working at that for some time, to give a little attention to it and to give me a report on it, and I will be very glad to hand you that report. (*Vide* Appendix.)

1461. I do not refer so much to what you yourself have found out, but I am asking whether or no you think a physical laboratory could help you in such an investigation?—I think it would. The difficulty in regard to the physical laboratory is to limit its scope; I would like to limit it absolutely to the question of standards, and standards only, and to any such research as might be necessary in connection with those standards.

1462. Would you include in that, in the case of electrical standards, for instance, investigations into the specific resistance of materials?—Yes, certainly.

1463. That would leave, I should think, a considerable number of questions of that type, which could be usefully undertaken, and researches made by the Institution?—Certainly, it would give a very large field, I believe.

1464. Do I understand you to mean that you do not think that these problems should be suggested by practical men to the laboratory, but should simply arise out of the necessities of its own work in connection with the standards?—I think that if there are certain things that the Committee of Management or the governing body, whatever it may be, consider it is necessary to make investigations into they ought to be empowered to do so.

1465. Would you allow the individual manufacturer to send in specimens of a new insulation and to require that that insulation should be tested?—Certainly not.

1466. For what reason?—Because I believe that would be an endless task to undertake purely from the point of view of the practical working of the laboratory. I should think that a thing of that sort should be submitted to the governing body, and if they think it is really worth while

investigating, then the Superintendent of the laboratory could be instructed to investigate.

1467. You would not give the individual manufacturer the right to demand such aid?—No.

1468. But you would give the governing body the right to select problems in which such aid should be given?—Quite so.

1469. Then with regard to the question of the fitness of platinum silver as a material for resistances, do you think that is a problem which such an institution ought to take up?—Certainly.

1470. It would be useful to the trade?—Certainly.

1471. Then, of course, manganin is now coming in a good deal?—Yes.

1472. Do you think that the introduction of manganin has been due at all to the action of the Reichsanstalt?—I believe it is absolutely due to them, and nothing else.

1473. In what way is it due to them?—I believe they investigated into the question, and it is now known as the result of their work that manganin will be a thing that we can employ for resistances.

1474. The investigations of the Reichsanstalt have given confidence in the use of that material?—Yes.

1475. (*Sir John Wolfe Barry.*) Do you know how the investigations in to the qualities of manganin arose at the Reichsanstalt?—From a technical point of view I cannot say.

1476. (*Mr. Rücker.*) Then, to pass on to the question of the government of the Institution, you have heard the answers Mr. Swinburne gave; may I put to you the same question—Do you think a governing body, nominated by the Royal Society, under the conditions that industry is to be largely represented upon it, and that it should not be confined to Fellows of the Society, would have the confidence of technologists?—Speaking generally, yes; but my own view would be that, if there is a National Physical Laboratory established in England, we have to remember that in this country we have large colonies, and that we must consider, to a certain extent, their views in the matter. I think that if the Royal Society, in making their selection, were to take that into consideration, it would be well worth while doing. In fact, I roughly drew up a note of what I think might be done. I took the suppositious case that if the governing body were a committee of fifteen, probably there should be two representatives of the Board of Trade, one of the Colonial Office, one of the Foreign Office, and one of the Treasury; that two Colonial Government representatives should be appointed, and that the eight others should be absolutely technical men. The reason for suggesting some of the other names is purely, I will not say, time serving, but it is on account of having the power, for instance, of the Colonial Office in dealing with the Colonies, and of having the power of the Foreign Office, perhaps, for any international arrangements with the Paris Laboratory or the German Laboratories; and the Treasury, of course, is all important from a money point of view. It might please the Colonies to know that they had two men to be appointed by them on such a governing body. That is the idea I had; but, still, I am perfectly at one with Mr. Swinburne on the fact that the Royal Society should be the body to deal with the Government for the selection of the governing body of the Physical Laboratory.

1477. Of course, those gentlemen you have mentioned from the various Government offices would be of no direct use in controlling the scientific work of the Institution?—No. I should fancy it would fall absolutely into the hands of the other eight.

1478. So that that would be in that sense reducing the number of representatives of science and technology very considerably?—Yes, if it consists of fifteen members.

1479. You are probably aware that the Royal Society is frequently in official communication with the principal Government offices?—Yes; but that is not the same, I should think, from my point of view, as having men that are in the offices on the Committee.

1480. The Royal Society has a great many Colonial Fellows, and is in touch with the Colonies in that way?—I quite understand that.

1481. But, still, you yourself would agree to such a constitution as has been roughly sketched out?—Certainly; I would agree perfectly with the recommendation of the Royal Society in the terms that Mr. Swinburne mentioned.

1482. (*Sir Andrew Noble.*) As I understood your evidence, you would consider that the Physical Laboratory should confine itself solely to what we may call standardising work; that is to say, to establishing standards, and to any problems that might arise therefrom. Did I understand you aright?—Yes.

1483. The Reference to this Committee includes another wide field, namely, the determination of physical constants; is it your view that that is not work which would be profitable to the commercial part of the country?—Naturally, it is a very useful and a very important thing; but the bother in considering the whole thing is to limit the scope of it, which is very difficult.

1484. That we quite understand; but we are all of us aware of the large number of physical constants that a physical laboratory might indulge in; but we assume that the controlling committee or governing committee, whatever we like to call it, would specify and direct what physical constants should be done by the Physical Laboratory, and what should be left for the determination of private scientific men who would examine into those points?—I believe that that is a question that ought to be left to the governing committee to determine as to how far they should go.

1485. Then I rather gather that you would exclude the determination of physical constants altogether?—I tried to say that research resulting from the fact that the laboratory was a standardising laboratory, might include fees for the working out of the constants, and of the testing. Still, shortly, I believe that it is absolutely necessary that the Physical Laboratory should undertake their determination. I do not see any way out of it.

1486. (*Sir John Wolfe Barry.*) Take the analogy of manganin: supposing such a substance was a promising substance and seemed to require investigation, and it was brought before the managing committee, and reasons shown for investigation, would you think it would be a proper matter for investigation?—Certainly.

1487. You would leave the selection to the managing committee?—Certainly.

1488. Do you keep a laboratory of your own at your large works?—We have chemical and physical laboratories; they are divided out a great deal—sometimes they are attached to different departments.

1489. Can you give us any idea of the expenditure your firm undertakes in what might be called laboratory work, as distinguished from manufacturing work?—It is difficult to say.

1490. One would want to know how much money was being spent by a firm like yours on investigations, some of which, if not all, possibly might be undertaken by the National Laboratory. I rather wanted to know what has been spent by great firms in the investigation of physical questions?—It is really very difficult to answer.

1491. At any rate, you spend a very considerable sum of money in investigation?—Yes; a very considerable sum of money. A building is sometimes put up, and the tests are taken, and the staff are busy at the testings; and machinery is sometimes built for testing purposes. It is very difficult to say how much the cost would be.

1492. Have you got a salaried scientist?—We have two or three.

1493. I mean at the head of the investigation department of your business?—We are supposed to have two or three.

1494. For testing materials or investigating or standardising instruments?—Yes. One of our men acted as secretary to Section G of the British Association. We have two or three men like that connected with the business.

Wednesday, 15th December 1897.

PRESENT:

Mr. A. W. RÜCKER, D.SC., F.R.S. (in the Chair).

Sir COURTENAY BOYLE, K.C.B.
Sir ANDREW NOBLE, K.C.B., F.R.S.
Sir JOHN WOLFE BARRY, K.C.B., F.R.S.
Mr. W. C. ROBERTS-AUSTEN, C.B., F.R.S.
Mr. ALEXANDER SIEMENS.

Mr. L. BLAIKIE, *Secretary*.

Right Hon. Sir B. Samuelson, Bart., F.R.S.

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The Right Honorable Sir BERNHARD SAMUELSON, Bart., F.R.S., called; and Examined.

1495. (*Mr. Roberts-Austen.*) You were a member of the Duke of Devonshire's Commission for the Advancement of Science and Scientific Instruction, were you not?—Yes.

1496. You were also Chairman of the House of Commons Committee on the Patent Laws?—Yes.

1497. You were also Chairman of the Royal Commission on Technical Instruction?—Yes.

1498. And you are a past President of the Iron and Steel Institute?—Yes.

1499. I know you represent the Iron and Steel Institute here?—Well, I have been nominated to represent it, but I have had no conversation with any of the members, and I do not know how far they would agree with what I may say; I suppose, to a certain extent, they would be responsible for it.

1500. Yes, I am sure they will. You consider that the establishment of a National Physical Laboratory is desirable?—Yes.

1501. Will you tell us why?—I consider it desirable. The only question, to my mind, is whether the terms of reference cover all that we should like you to do. There is one thing that it certainly does cover, and that is reports as to apparatus for registering the changes of electrical resistance at high temperatures. That is a very important thing for us. Those pyrometers are of very great use to us, and, of course, we are anxious that they should be reliable; and we should be very glad also that they should be simplified, if that be possible, and that is certainly covered by your reference. Whether the investigations into physical facts, which we would like you to examine, are also covered is another question; but, I suppose, under any circumstances, if it were desirable that such a laboratory should be established, the question of what should be its functions would be one which would receive consideration by yourselves in the first instance, and by the Government afterwards. I see that you are requested: "To consider and report upon the desirability of establishing a National Physical Laboratory for the testing and verification of instruments for physical investigation." There is nothing said about chemistry.

1502. Do you think there are many questions likely to arise in connection with the iron and steel industries that would involve chemical investigation?—I have no question at all as to that; I am certain of it. But at the same time this appears to me to be evident: that the chemical investigations, as not being dependent upon time so much as physical investigations, do not stand altogether on the same footing. Now, as an instance as to where investigations into physical properties would be of the greatest use, and involving researches occupying a considerable space of time, I might name the questions of stress—stress continued for a considerable length of time, and stress interrupted and renewed. That species of investigation would be very difficult indeed to be carried on otherwise than in a well-appointed laboratory; and we, of the Iron and Steel Institute, certainly have not the means of carrying on any investigation of that sort. Whether the universities would undertake it, or whether it should be undertaken by a National Laboratory, is, of course, a separate question. We should be glad to see a National Laboratory do it, because we are not aware that anything of the kind is done elsewhere, unless, perhaps, to a limited extent, at the University of Glasgow, under Lord Kelvin.

1503. And such investigations would be of great service in connection with the strength of structures and the durability of structures?—Most decidedly.

1504. And of machinery?—Yes. Then, again, there is the question of the effect of concussion upon metals used in the Arts; for instance, the effect of concussion long continued upon rails, upon axles, and generally upon metals used in various structures. Then there is the question of the effect of time on what you, I think, call the flow of solids. I think there, again, time is required, and investigations of that sort should be continued over a long period. I am not aware that there are any investigations of that sort now being carried on systematically in any existing laboratory.

1505. And such investigations would be of great importance, as the almost imperceptible flow of a metal would lead to a distortion and possible failure of the structure?—Yes, exactly. Then, again, the question of alloys arises, and that is one which I should have been glad to have seen more fully covered by your reference. We have at this moment an introduction to a very large extent of tubulous boilers. We do not know what is the best composition of steel for the tubes of those boilers, and although there may be no difficulty in obtaining a metal which will resist for some length of time, it is quite possible that it may be found that a certain alloy would, during a long period of time, resist abrasion, or deformation by pressure very much more satisfactorily than another. That, again, is an investigation requiring a considerable length of time; and look how important that is to the nation! We are now introducing these tubulous boilers to an enormous extent into our Navy and into our merchant service, and if it should be found that one alloy of steel rather than another is suitable for that purpose it may save us from very great loss, or, on the other hand, through an ignorance of these facts, we may incur very great loss, not merely the replacing of the boilers, but the pulling to pieces, almost to destruction, of the vessels in which they are contained. Another instance, somewhat analagous to that, is the system which is now being introduced, with which I am myself concerned, of what I may call an accumulator of heat, just as you have accumulators of electricity. In the Serpollet system, with which, no doubt, the Committee is acquainted, the tubes are raised to a very high temperature—to a bright red heat; water is injected instantaneously, converted into steam, and used in order to produce energy in the cylinder. We do not know how long these tubes will last, we do not know what is the best material of which to construct them in order that they may last a long time, that they may resist pressure, and that they may not scale. That, again, is one of those investigations requiring time, and which a Physical Laboratory could conduct with very great advantage.

1506. Researches that could hardly be undertaken in private laboratories, could they?—It is very difficult to undertake them in private laboratories, and so it is almost impossible to say what else may arise in the course of time, or even what is necessary now to be undertaken in the interest of the Arts.

1507. There is one point I should like to be clear upon; in using the word "alloy" you were always contemplating the alloys of iron with some other element?—Yes, with some other element. Of course the same thing applies to brass, but I was thinking merely of alloys such as nickel and steel, and chromium and steel.

1508. Then as regards the constitution of the governing body of such a laboratory as it is proposed to establish, what are your views on that subject?—I think men of science ought to be represented on it, certainly.

1509. And the Royal Society be the governing body?—Yes, I think the Royal Society has shown its fitness to be the governing body of such an institution.

1510. And the Royal Society, then, I gather, would nominate the members of any committee that might assist the Royal Society in governing it?—No.

1511. You think not entirely?—Not altogether; I be-

lieve that it might very well be entrusted to the Royal Society except for what I may call a political reason, or an economical reason rather, and it is this: that I believe that although, probably, the Royal Society would nominate the same individuals as might be nominated by certain other bodies, that there would be greater satisfaction on the part of those bodies, and that there would be no detriment to the Committee if the bodies themselves were asked to nominate the members.

1512. Such bodies, I suppose, as those which have already sent members to represent them here before this Committee—such as the Civil Engineers?—Yes, the Civil Engineers, the Mechanical Engineers, the Electrical Engineers, and, if I may say so, the Iron and Steel Institute.

1513. Then with regard to the publication of investigations—that is a question of some importance. Should all the investigations be freely published, do you consider?—All except those, I think, which were committed to them by the Government.

1514. For a special purpose?—Yes, for national purposes. I do not see how you could refrain from publishing your investigations. If they were to be conducted for private profit there would be questions of who is entitled to have such investigations conducted, and who is not. You might derive some pecuniary advantage from conducting them, which would fail in the other case, but I think the other view, namely, that everything done by a public body appointed for a public purpose, should be for a public purpose, and should be published, would far outweigh any small fees that you might obtain.

1515. Other witnesses have stated that the work would be to a great extent remunerative—standardising work, and work of that kind, would be remunerative; do you think that would be the case as regards iron and steel?—No. I do not think it would. There are two classes of work—I could quite understand that standardising and work of that sort might be paid for, but that is a different thing altogether from such investigations as I contemplate.

1516. (*Mr. Rücker.*) You think the various Government Departments should have a right to apply to this laboratory for scientific help if they wanted it?—Certainly.

1517. And in that respect it would be useful to the country?—Yes, I pointed out an instance where I think it would be of the greatest use, and that is in this question of tubulous boilers. I believe that a body of this kind might save vast sums of money to the public by their investigations.

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1518. Do you think it would be desirable that this body should have any relation with the other standardising Government institutions which already exist, such as the Standards Office and the Board of Trade Laboratory?—Yes. I think it should have a directing alliance.

1519. (*Sir John Wolfe Barry.*) I did not quite follow your view about the nomination of members; you said, I think, that you thought the Royal Society would be a very proper body as a governing body?—Yes, as a controlling body.

1520. Do I understand you rightly to say that you would add to the Royal Society nominees of other societies?—Yes, subject, I should say, to their consent. But I would like it to be understood publicly by the various institutions of a technical character that the nomination has taken place by those institutions themselves, and I do not see any drawback that could arise in that.

1521. Then you would add these nominees to the nominees of the Royal Society?—Just so, they should form part of the Committee.

1522. Have you thought whether the Government should be directly represented on the governing body?—No, I think it would be very much better that the governing body should do in regard to this as it has done in regard to other investigations—I think in regard to the Meteorological Council, is it not so—that the matter should be left in the hands of the Royal Society. There is always one great control that the Government has, and that is the control of the Treasury.

1523. The power of the purse, that, in your view, would be enough?—I think it would be quite sufficient. I do not think that the Royal Society or the Committee could go very far wrong, so long as the Government retains the power of saying: Thus far shall you go in spending, and no further.

1524. And naturally they would report to the Government half-yearly or yearly what was being done?—Yes, through the Royal Society.

1525. (*Mr. Siemens.*) I should perhaps first ask your opinion about the suitability of Kew, whether you think that the buildings at Kew could be added to, and so to establish this laboratory there?—I do not know whether the buildings at Kew could be added to, but I think buildings could be erected at Kew as being a suitable site for such a laboratory; it is isolated, and at the same time it is not far from London, which, after all, is the centre of affairs.

Dr. JOHN HOPKINSON, F.R.S., called; and Examined.

Dr. John Hopkinson, F.R.S.

1526. (*Mr. Rücker.*) You are interested in technology?—Yes.

1527. You are also a Fellow of the Royal Society?—Yes.

1528. And have devoted a good deal of attention to scientific research?—Yes.

1529. And you are ex-President of the Institution of Electrical Engineers?—Yes.

1530. Have you given any attention to this question of the possible establishment of a National Physical Laboratory?—Yes, some, not a very great deal.

1531. Do you think that there are any classes of scientific investigation which could be better carried on in a public institution of that sort than otherwise?—I think so, and not only better carried on, but that there are many classes of investigations for which there is no adequate motive for individuals to carry them on—not to carry them on, at all events, to the extent to which it is desirable that they should be extended.

1532. It is work that would be better done by officials than by individuals you think?—Yes, it would be done by officials if they were paid to do it, but it would not be done properly by individuals who were not interested to carry it through.

1533. The ordinary motives which lead to research would not in this case apply?—No, I think not. There are many investigations of that kind.

1534. Could you illustrate that?—Yes, there are many things; for example, investigations into the constancy of physical qualities, which must last over a very considerable length of time. You might take electrical resistance, for example. That, of course, has been done to a certain extent by private enterprise. Perhaps it is rather surprising to many of us that it should have been done, but it would be very much better done by a public institution, where there were paid officials to carry it on, and to continue the work—when one man left for another to take it up. Another thing is the colours of glass, for example. Of course, we all know in the process of time many glasses will change their colour. It would be important to know under what conditions those changes occur, but an investigation of that kind necessarily takes a long time, and would be, therefore, better done by a public institution in which there was some continuity than by individuals with whom the work would cease when they ceased to be able to carry it on. Another thing is the elasticity of metals. Now, Lord Kelvin has been working at that for a long time undoubtedly, but whether if Lord Kelvin were no longer there the work would be continued is very doubtful indeed. Another class of things would be the determination of physical constants of many kinds. Of course, when a private investigator has done a few types he will not care to pursue the subject further; the interest, as a rule, is gone; but at the same time, it would be very desirable in the interests of manufacturers, and so on, if determinations of that kind were made systematically and continuously, without regard to whether the investigation was one which continued to be interesting to the investigator or not. Then, again, there is the standardising of instruments. This is, of course, largely provided for in the institutions which exist. Thermometers to a certain extent are done at Kew, though, as I understand, not so completely as would be desirable. Chronometers are done, too, I think, at Kew and at Greenwich. For a time, of course, with regard to electrical instruments there was no public institution which touched them at all. Now the Board of Trade have provided a special machinery for dealing with a considerable class of electrical instruments so far as is necessary for trade purposes. But in every case it has been necessary, or almost necessary, to establish some new public department, or to extend the work of the existing department. Of course, from time to time, as fresh matters of study come up, and fresh classes of instruments are re-

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quired, it would be a good thing if there were some institution whose duty it would be to provide a fresh establishment to deal with the standardising of such instruments.

1535. But take the case of the Board of Trade Laboratory, the standards which are used there are used in connection with a science which is in a state of progress?—Yes.

1536. And it is probable that in future even a higher degree of accuracy would be required than is attained at present?—I do not know for trade purposes whether that would be so or not, but it may be, of course.

1537. At all events, it is desirable that the scientific accuracy attained should be, as it were, one step better than that used in an institution meant for trade purposes only?—I would say two or three steps better. It ought to be so good that no question could arise as to the accuracy of the scientific part of the matter.

1538. Do you think it desirable that the Board of Trade should be supported by a scientific institution in which such investigations are carried on?—I should think it would strengthen their position materially. I would not like to see the Board of Trade Laboratory superseded by any means; I think the work there done is done thoroughly well.

1539. You think that a scientific institution such as is now proposed would be a useful adjunct to the Board of Trade?—I think so, and not only to the Board of Trade Laboratory, but for dealing with other matters which are sure to arise from time to time. Supposing that we had had such an institution as this in existence when that Board of Trade Laboratory was founded, that institution would naturally, and easily, have dealt with the matter without the Department being put to the trouble of establishing a new institution. But the institution having been established, and working well, I should not disturb it.

1540. Have you sufficient acquaintance with the Kew Observatory to express an opinion as to whether or not the development of that would be one of the best courses to adopt?—No; I know very little about the Kew Observatory: what I know is mainly by hearsay.

1541. With regard to the government of the laboratory if it were established, do you think it desirable that the Royal Society should be the body responsible to the Government for its management?—I think so. Of course, if you give it to a scientific society at all, or a technical society, it is the only society which could deal with it; there is no other society which would completely cover the whole ground to be dealt with.

1542. Do you think it desirable that technology should be represented on the committee which actually manage the laboratory?—Certainly.

1543. Do you think it would be sufficient if it were definitely stated and understood that the members of the committee should, some of them, represent technology, and that they need not necessarily be members of the Royal Society?—I think it would be a useful provision.

1544. Do you think that the technical societies generally would be satisfied with that?—I think so. I do not think there would be the least jealousy of the Royal Society on the part of any society.

1545. Provided those conditions were fulfilled?—I do not think there could possibly be any jealousy. I think they themselves would feel that they had not got the general view which the Royal Society itself could give.

1546. (*Sir Andrew Noble.*) I suppose you consider that even taking, for example, the Board of Trade, as being very satisfactory, it is desirable that they should have a high consultative authority to back them up, or to give them information should they require it, such as the laboratory to which we are referring would be?—Yes, it would strengthen the position of those who have to manage the Board of Trade Laboratory very materially, I think.

1547. You said you did not know very much as regards the Kew Observatory; but I suppose you would agree that the position of the Kew Observatory would be preferable to any position in London for such a physical laboratory?—It would be exceedingly good, undoubtedly.

1548. Some of the things you have referred to could not very well be carried on in London on account, for example, of the traffic?—Quite so.

1549. And also on account of the currents of very high tension—I am speaking now, of course, of the electrical case?—Yes; I think no doubt it ought to be, not in the heart of London, but some little way out. Take the Reichsanstalt, of Berlin, that is in Charlottenburg, not in Berlin.

1550. Perhaps it is hardly a fair question to ask of you, but referring to physical constants, could you name any particular physical constants that at this moment you consider of importance that could be referred to such a laboratory?—Of course, anything one gives would be merely by way of illustration.

1551. Yes, merely by way of illustration?—Take the extensibility of materials, and so on.

1552. And also the changes in long periods of time?—Yes, that, of course, comes under a different department. The mere determination of the constants, I think, would be very much better done if it were done systematically by an institution of that kind, and the results stated in a definite way so that anyone who wished to know a fact would be able to interpret the results, having once acquired the method of stating they have adopted, instead of having to read, as he would have to read, to get his information, a number of papers in which the results were stated in different ways. Then, of course, taking the same illustration, now, if a new material, a new alloy possibly, or whatever it may be, is brought out either some individual will determine its properties for himself, and if it is of value will keep it for himself, or it will not be done at all. If you had a central institution of this kind you would have it done systematically, I should hope.

1553. Then I rather gather it to be your view that the officer in charge of this should be practically the best man you could obtain?—I think so.

1554. But that at the same time he should be subject to a visiting committee, who would include not only the Fellows of the Royal Society, who are pure physicists, but in addition certain technologists, who might, or might not, be Fellows of the Royal Society?—Quite so. I would have it well understood that it should be representatives of different departments, not only of pure, but of applied, science as well.

1555. (*Sir Courtenay Boyle.*) Should they have the control of the money?—I do not think I have given any consideration to that.

(*Sir Courtenay Boyle.*) That is rather an important point.

(*Sir John Wolfe Barry.*) It depends upon what you mean by "the money."

(*Sir Courtenay Boyle.*) The money given by the State.

(*Witness.*) The distribution of it; of course you have plenty of precedents for the Royal Society controlling the distribution of public moneys.

1556. Supposing they should, then that is another question. Would they be able to limit the number of investigations that would be asked for, and would have to be undertaken?—That might possibly be limited by the funds available. If the resources were ample I should not be disposed——

1557. Theoretically yes, but practically no, because if the demand is greater they would come for more State funds at once?—Still, if the work being done was found to be useful I do not know that that would be a matter for regret.

1558. Take physical constants; are not the number of physical constants which would have to be determined almost unlimited?—They are very numerous, of course; but I was not referring so much to the determination of new constants as to constants of new materials. There are many things which everyone wants to know about a new material.

1559. Take electrical resistance, should not we have to determine an enormous number of electrical resistances?—You might have to determine a good many; but the interest of resistances and alloys is nothing like so great in many cases as the strength of material and the extensibility, and so on.

1560. And your object would be that the laboratory should be used for high physical research rather than for the testing of the behaviour of commercial instruments?—By no means. I would include amongst its duties the testing of commercial instruments; but I would regard that as a very minor part.

1561. Could it not be made self-supporting?—The testing of the instruments?

1562. The testing of commercial instruments for commercial purposes?—It is possible enough. I do not know. How do you do it at the Board of Trade; you probably know better than I do?

1563. They are trying, as a new experiment, to see whether it can be self-supporting; if it is not, I do not know whether we shall be able to go on with it?—It will be a great pity if you cannot.

1564. Is it the duty of the Central Department of the State to test an individual's instrument?—I would not say that it was the duty, but it may be a convenience to society that the State should do it.

1565. Can you tell us where the State's function comes in in the matter of testing instruments?—I put it in this

way, that it is a thing which will be of use if done by the State; it is a thing which you have done in the past by State institutions, and done it almost up to, so far as the demand goes, the present time, so that I put it that the proposed provision would be for testing new classes of instruments rather than existing classes.

1566. As regards the electrical testing, would you abolish the laboratory here altogether?—Certainly not. I think that laboratory works exceedingly well, and I certainly should not disturb an institution which is performing its functions in a thoroughly satisfactory way to my mind.

1567. So far as it goes, in your opinion, it is doing good work?—Yes, certainly.

1568. (*Sir John Wolfe Barry.*) I do not think you told us, but I think you represent the Institution of Civil Engineers here?—Yes.

1569. I think one can almost say that there is no public body which conducts any, what I may call, public investigations into the strength of materials?—I think not. I think that it is all done by private individuals.

1570. It has been done, of course, and I do not mean to say that it has never been done; but I mean that as a system there is no body at the present moment which would undertake to give answers as to the behaviour of a certain alloyed metal?—No; but there are people who will do it for you, and do it in their own private laboratories.

1571. You mean private individuals?—Yes.

1572. There is no public body?—I believe none, so far as I know.

1573. Therefore, if you go to a private individual or a private laboratory for that purpose the information given is private information, and does not belong to the public?—Certainly; you pay for it, and it goes no further unless you desire it.

1574. And the public would have no access to any investigations which are made into such matters at the present time?—No, unless the party having it done chooses to publish it; or he publishes it in his own way, and in his own units, and you have to ascertain the form of his expression before you know what he means.

1575. Unless you know that he has done it you may not get hold of it at all?—No.

1576. Are you aware that the Mechanical Engineers have made certain investigations into friction and matters of that kind?—Of course, they have not done determinations of constants or anything of that kind.

1577. As a generalisation there is no public body whatever who can give an answer as to the behaviour of materials under stress?—No, I think not. Of course you may except some of the colleges where they happen to have testing machines; but there I take it it would be regarded as the property of the person who brought the material.

1578. Usually at colleges I think the testing apparatus is paid for by the individual who wants it used, and he takes away his information, and it is not necessarily public?—Yes, as a rule I believe that is so.

1579. Then I should take it that your opinion would be that the publication of information of this sort, which would be exhaustively undertaken, would be of great commercial value to the country?—I think undoubtedly it would be a very great convenience to know that you would be able in all probability to find the properties—to keep to our old instance, the co-efficient of elasticity of any material that was known, published in a known form in a known place.

1580. I daresay you are aware that there is a very important investigation going on as to the behaviour of steel rails under fatigue?—Yes; that, of course, will take a long time, and for that reason would be a desirable subject to be conducted by a public institution instead of by an individual.

1581. That would be a very good illustration of some of the things which you have in your mind?—Certainly.

1582. I presume therefore that you would be of opinion that these investigations, spread over a variety of laboratories, must involve a great loss of money in the aggregate as compared with the results which the public obtain?—Probably it costs a great deal more, and the work is not done in quite that systematic way which would be desirable to make the results thoroughly convenient and available.

1583. Nor are those results available to the public?—No, not necessarily.

1584. Would it be your opinion that when investigations of this nature take place that a national physical laboratory should be open to the whole public?—I think so. If you take anything there it should not be your property at all, it should be the public property.

1585. I presume, therefore, the way in which information would be given would be by an annual report or a semi-annual report?—Yes, the way it would be done is that the work done would be published under its proper class, and if that material, if it were a material, was brought by an individual, that you would at once communicate the result of the investigation to him, but that it should not be regarded that he had any exclusive property in that information.

1586. You think that these investigations such as you indicate would have very great commercial value to the trade of the country?—I think so, if you consider the comparatively moderate cost of the thing. I should think it would be paid for over and over again every year.

1587. (*Sir Courtenay Boyle.*) I wish you would develop that argument so as to get it on the Notes, why it would be paid for over and over again?—Take the case of the strength of materials, I think we must deal with them almost in that way. I do not know what the cost of determining the properties of an interesting material, let us say, an alloy of aluminium would be—it would be exceedingly small. If the material was of any value at all, for any purpose, surely the cost of that determination would be returned many hundredsfold?

1588. (*Sir Andrew Noble.*) Do you think it would be returned to the country?—Yes.

1589. (*Mr. Rücker.*) By the fact that a good material would be generally used instead of an indifferent one?—You would know then what your material was. On the other hand, if you had got to put up your apparatus, and to make the test for yourself, it would cost actually to do it many fold what it would to be done in the institution, and the benefit to the community would be very much less, because it would not be public property, it would be only the property of the individual.

1590. And the result would not be generally published?—It may or may not be published; but if published probably it would be published in a comparatively inaccessible form.

1591. It generally is not published?—I daresay you know the large amount of investigation that is done which is not published, better than I do.

1592. (*Sir John Wolfe Barry.*) You might take another analogy, I suppose, from the subject I mentioned, namely, steel rails; an investigation of that sort affects the industry of an enormous number of people?—Oh, dear, yes; the output of the smallest of your rail mills would be many fold the whole cost of this laboratory.

1593. (*Mr. Roberts-Austen.*) You were speaking then, were you not, of the failure of rails under excessive use?—Yes. The suggestion is that rails, owing to continual vibration, become a different material from what they are when they are new.

1594. But that is not exactly the work that has been submitted to the Committee now sitting; you are contemplating some other work, are you not?—No, that is the illustration, as I understood, that Sir John Barry put to me; is that not so?

1595. (*Sir John Wolfe Barry.*) The illustration I had in my mind was this: that assuming that steel rails are found under fatigue as at present manufactured to be susceptible of degradation in quality, and assuming also that that had been shown to exist at a National Physical Laboratory, and that by adding some alloy to the steel that liability could have been avoided, the value to the whole country would have been enormous?—Oh, dear, yes; the cost of the laboratory would be a mere drop in the bucket. Of course, any illustration might be objected to easily enough, but amongst those you would not find very many in which the return would not be enormously great as compared with any cost that would be incurred.—(*Sir Andrew Noble.*) To follow Sir John Barry's illustration, they could also examine whether it was possible to remove the effect of the fatigue to which you refer.

1596. (*Sir John Wolfe Barry.*) Exactly—by another process, whatever it might be?—At all events it would be presumed that you would learn which materials were subject to that and which were not, if there were two classes.

1597. There I gave an illustration why it seems to me that that is a kind of investigation which no manufacturer of steel rails could possibly undertake for himself?—No, and if he did, how is he to get the benefit of it? He cannot prove, excepting after a long time, that his rail is a better rail; if he could prove it and satisfy the public he would wish, if he could, to keep the information to himself, quite rightly and properly.

1598. (*Mr. Roberts-Austen.*) Am I right in thinking

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that the Institution of Civil Engineers has had, until recently, no power under its statutes to appoint committees for research?—I am not sure; I do not remember.

1599. As a matter of fact, it has not appointed any such committee?—No, not yet; but the Mechanical Engineers, as you know, have. But they have been doing rather work which would otherwise be done by individuals, and not a class of work to which I am alluding in connection with this laboratory.

1600. (*Mr. Siemens.*) I only wish to bring out one point a little more, that is, you meant that the investigations which are now being carried on by private people are carried on just as far as their immediate necessities compel them to carry them?—Yes, or the interest of the subject may take them.

1601. An institution like this would do the drudgery work?—Clearly.

1602. And carry them right to the end?—Yes, it would not be in any way a substitution for individual effort.

1603. No, it would rather be that portion of the work which does not bring great renown and which does not bring much money?—That is so.

1604. But which is very necessary all the same?—Yes, that is exactly my view—to do that which there is not enough motive to induce the individual to do.

1605. (*Mr. Rücker.*) I should like to ask one question more on the point which has been already mentioned, in regard to the publishing of results. I think I can best illustrate my meaning by an example. If a maker of thermometer glass sent in a glass and asked you to examine its properties after it had been heated, the importance of that information to him would depend upon the knowledge of its chemical constitution at the same time?—Yes.

1606. Would you allow him to put the question to the laboratory as regards physical qualities only, the answer to which they would then publish, but subject to the condition that the laboratory should be debarred from entering into the chemical question in the published account of the investigation?—No, I think I should insist that he should make a clean breast of the whole thing.

Sir William Anderson, K.C.B., F.R.S.

Sir WILLIAM ANDERSON, K.C.B., F.R.S., called; and Examined.

1607. (*Mr. Rücker.*) You are Director-General of the Royal Ordnance Factories?—Yes.

1608. You are a representative of the Institution of Civil Engineers?—Yes.

1609. Have you paid any attention to the question of the possible establishment of a National Physical Laboratory?—Not very much; I have often thought of it.

1610. What special purposes would you think such a laboratory would serve?—For standardising any instruments which are very much out of the common.

1611. Instruments which are required for the researches of individuals, or for wider purposes?—For public and private purposes.

1612. Have you found in your own work at Woolwich the necessity for the standardisation of such instruments?—Yes.

1613. Which has, I presume, been carried out by yourself?—Yes.

1614. What are your reasons for thinking that is not the best way of doing it?—Because in our dealings with the trade, with contractors, they are not always willing to accept our decision when a dispute arises.

1615. You would like some impartial authority?—I should like a central impartial authority to which anyone could refer.

1616. Could you mention any instruments in the case of which you think such investigations are specially desirable?—High-temperature pyrometers, for instance; high-pressure gauges; instruments of that class which are not very commonly used, and which require expensive apparatus to standardise them.

1617. Do you know whether there is any public body that tests pressure gauges at present?—Not exceptional gauges; I do not think there is.

1618. Or even those for ordinary steam engines?—I do not know whether Kew would do it or not; I am not sure.

1619. But unless Kew, you know of none?—I know of none.

1620. Do you think it desirable that that should be undertaken?—I think so. I think it requires a public authority, which everyone can appeal to.

1621. With regard to instruments for the measurement of velocity, what do you say?—That is the same thing; there is nobody who can standardise those excepting the persons using them.

1622. And yet cases arise where it is desirable that some public body should be able to undertake that?—Disputes have arisen about the ballistics of guns ascertained by the makers of guns as compared with the ballistics ascertained at the Government ranges.

1623. And, therefore, you would like to call in scientific aid in addition to that which you have at present at your hand?—Yes.

1624. In the case of investigations which you have carried on, do you find, in the situation of the Woolwich Arsenal, or from any other cause, special difficulties have arisen?—Yes, the Royal Arsenal is on a marsh, and the ground is quakey—that is the best term I can give to it. We recently established, or attempted to establish, a method of testing the quality of brass alloys by Dr. Roberts-Austen's cooling curve method, but we found that the ground shook so during working hours from the vibration of the machinery, and in the silent hours from the street traffic, that the instrument was quite useless.

1625. Is it necessary, therefore, that there should be a laboratory in some better chosen situation?—Yes.

1626. Do you, as the head of a great Government institution, think it desirable that there should be a central body, to which the different Government institutions can apply for scientific help if they want it?—Yes.

1627. That, put shortly, is one of your main views?—Yes, that is what I think.

1628. Then, with regard to the management of such laboratories, have you formed any view as to what the government of the new laboratory should be?—I think it had best be vested in the Royal Society.

1629. Do you think it would be desirable that technology should be represented?—Yes, I think technology ought to be represented, certainly.

1630. And the actual governing committee should not necessarily consist exclusively of Fellows of the Society, probably?—No.

1631. Do you think, as a representative of a technological institution, that technologists generally would be satisfied with the appointment of the committee by the Royal Society, provided these fundamental conditions were complied with?—I am sure they would.

1632. You do not think it would be regarded as essential that the great technical institutions should themselves nominate members?—No, I do not think so.

1633. With regard to operations which involve a great expenditure of time, are those operations of a kind which are especially difficult to carry out in a private laboratory?—Yes, they are very difficult to carry out. Do you mean a commercial laboratory in a commercial firm?

1634. Yes, a commercial laboratory?—I think there are very few commercial men who would give the time and money that is necessary for long observations.

1635. And, nevertheless, there are investigations of that kind, which are of commercial importance?—Yes.

1636. (*Sir Courtenay Boyle.*) As the head of a Government department, you consider that your power of dealing with contractors and others, in the interests of the public, is impaired by the fact that there is no standardising laboratory to which you can appeal?—Yes.

1637. (*Sir Andrew Noble.*) Of course you are aware that there are very many cases, that frequently come before you, where it would be to the great advantage both of the country and of the Government, that either party should have the power to appeal to an independent scientific body like the governing committee of the Physical Laboratory we are contemplating, to give an answer which would have great weight upon these disputed points?—There is no question about that.

1638. And in your experience you have known many such cases?—Many.

1639. Then the Chairman has asked—I only want to add a little to the point, but there are many instances—that, for example, in the construction of guns, we will say, there are many questions arising there upon which we are very ignorant, and the experiments concerning which cannot, as you have said, be carried on in the Royal Arsenal. Such experiments could be carried on without very great expense in the Laboratory we are contemplating, and would be of immense importance to the country, would they not?—I think so.

1640. I will give as an instance the effect of secular stress upon the wire or other material of which your guns are constructed. We know very little about the

effect of that, and it is of very great importance?—Very great.

1641. And researches of that class could be properly conducted and without very great expense in such a physical laboratory?—Yes.

1642. (*Sir John Wolfe Barry.*) Apart from the locality and the circumstances attending the locality of Woolwich Arsenal, is there not also a question as to the experience of people conducting standardising investigations?—Yes, that is one of the great difficulties. To be able to use delicate instruments you require not only a sufficient initial training, but you require to be constantly at it, and we are deterred, really, from carrying out experiments simply for the want of officers of sufficient skill to carry out the experiments.

1643. Therefore, from that point of view, as well as from others, a continuity of existence of a laboratory is of great importance?—Yes. For instance now, supposing such a laboratory were established, there would be, of course, a large number of trained experimenters, and if the Government or anyone else required experiments to be carried out, for instance with guns, to determine velocities, or to determine temperatures, or anything of that sort, or pressures, it would be an immense help if a skilled observer could be detached from the Laboratory to proceed to the Arsenal or Shoeburyness, or Silloth, or anywhere else, to conduct the experiments.

1644. As a man experienced in the observation of delicate instruments?—Yes; for instance: the chronographs which are used in determining the velocity of projectiles, they are extremely complicated, especially electrical ones, and unless there is a skilful observer the results are worthless.

1645. I suppose there are very large questions at stake between the Government and the contractors?—Very often.

1646. Which should be determined by those means?—Yes, very often.

1647. Therefore, apart from the value to the country, there would be a very great value to the commercial world and the State in having these determinations made quite determinate?—Yes, I could give you an instance. Take cordite, which is occupying our attention very greatly just now. Sir Andrew Noble knows that we are quite ignorant at present of the effect of temperature upon it—that is, no law has been evolved yet upon the effect of a change of its temperature on the ballistics, and also upon the effect of the condition of the gun and the density of charge on the ballistics; and no consecutive experiments of any value have yet been undertaken, and I do not think are likely to be undertaken (unless Sir Andrew Noble undertakes to do it), to bring this to a satisfactory issue.

1648. (*Sir Andrew Noble.*) If you will allow me, I will interpolate here to say that I know that frequently not only cordite is rejected, but made up ammunition is frequently rejected, and it can be passed afterwards if it is presented under a different temperature or fired from a different gun. That costs the country a great deal, and it frequently costs the individual a great deal. If you had the power of appealing to a committee or to a laboratory such as we are considering, who will say: This has been examined chemically, and it has been examined as to its properties, and it does come within the specification, even although certain accidents connected with the gun, or with the temperature, had not given precisely the same results—that would be, in the long run, a saving to the Government, and in individual cases would be a great saving to contractors. Of course, we are obliged to consider all these things. Do you agree with what I have stated?—Perfectly; that is the bare fact. Of course, whatever makes it costly to the contractors makes it costly to the Government.

1649. (*Sir John Wolfe Barry.*) I suppose what you say of the matters at stake at the Arsenal must be true of many other large firms?—I think it is true of all large firms who manufacture warlike stores.

1650. I suppose it is not only true of warlike stores, but of almost every kind of work where there is a standard to be wrought to?—Yes.

1651. And to that extent it is not merely a question between the Government and the contractors, but is one affecting the whole commercial world?—Quite. If I may mention another instance, it is the case of the quick-firing cartridge cases which are drawn out of solid plates or discs of brass. Those cases are made of particular alloys; the copper for those alloys, or the zinc, requires to be of a particular quality or it will not produce the case. We have no means now of defining what the qualities are. We have no means of saying what the quality of the copper is to be, and we cannot define it. We generally specify Wallaroo or Lake Superior, or some place of origin of that kind; but whether we get it or not we have not the least idea, because it all comes through the hands of the merchant, and we have no test that we can apply, because to make a complete examination of the copper, bearing in mind what a large effect very small differences in composition have, is impossible. The only way that I can see is to make some electrical test for the purity of the copper. All that requires manipulation, which a contractor is ordinarily not able to give, and, therefore, we cannot frame a specification to ask them to do that which would be beyond their powers. Then again there is the extraordinary circumstance that although you twist or torment a plate of brass into this cartridge case, showing a most extraordinary ductility, yet many instances have occurred where those cases have cracked spontaneously afterwards; and we cannot trace a reason for that, and yet a crack in one of those cases might involve the safety of the gun and of the gun's crew.

1652. Before you were at the Royal Arsenal you had a very large commercial experience, had you not?—Yes, I had.

1653. Would the Committee be right in assuming that the evidence that you have given as touching the Royal Arsenal might, *mutatis mutandis*, be applied to the commercial world?—I think so decidedly.

1654. (*Sir Andrew Noble.*) As regards the standard of measurement, a laboratory such as we are referring to might not only define what the standard is, but also the way of using the standard, might it not?—Yes, certainly.

1655. I will give you an instance, and a very common instance—a point gauge, gauged at Woolwich and gauged at Elswick, I would say, to take as an instance, in the same micrometer, might differ by as much as one or two thousandths, dependent on the way of using it?—Certainly.

1656. The point is, that one, as an example, will let the point gauge drop, and take that as a measurement, and the other will hold it firm, and you can make as much as two or three thousandths difference in it?—Yes; we had a case of dispute of that sort in some rifle barrels sent to India. The gauges we sent out; they measured them in India, and they said they were not correct. They sent them back here, and we said they were correct, and there it remains now, one side saying one thing and another another, and there is no one to appeal to.

1657. There is a case now where things are made to thousandths; you never can be sure that a thing you make will pass?—Then there is another thing which you know very well, that different departments of the Government even use those gauges in different ways.

1658. Yes. I mentioned it the other day?—They do not use them the same way. It would be a great thing if we had a central authority to say that the proper way to use these is so and so.

1659. I will just interpolate, and see if you concur. We are making to the same drawing for the War Office and for the Admiralty; it will be passed by the War Office and rejected by the Admiralty, and *vice versâ*?—Very likely.

1660. Made to the same drawing; that is really a scandal?—There is another instance if I may mention it. I do not know whether I am out of order in suggesting those things.

1661. (*Mr. Rücker.*) No, please do so?—Take the case of the crusher gauges, by which the pressure of the guns is determined. They are made of copper; and, of course, to have a uniformity of record this copper ought to be the same quality throughout, and we have no means of defining what that quality is to be at all. It wants, in my opinion, a central authority, so that contractors and makers of guns who require to work up to the Government specification should be able to go to this central authority, and obtain the tests for the copper which are required. The only way we secure uniformity now is by supplying many of the contractors with the coppers ourselves. By doing so, of course, we take a certain amount of responsibility.

1662. (*Mr. Roberts-Austen.*) The Institution of Mechanical Engineers does devote a portion of its funds to the purposes of research, does it not?—Yes.

1663. You are Chairman of one of the Committees, are you not?—I am.

1664. Would you tell the Committee something about the work which has been undertaken?—I find I have got a statement here which I shall be glad to put in. Since 1879 the Institution of Mechanical Engineers has spent £4,374 in research. They had a Research Committee in 1879 on the best form of riveted joints; again, the hardening of steel; again, friction at high velocities: the value

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of steam-jacket; marine engine trials; the alloys research; rope and belt driving; the working of gas engines; and steam engine research—and of these the marine engine trials and the alloys research took pretty nearly the half of the money. The marine engine trials are at an end. These were conducted at sea with actual engines going considerable voyages. The Alloys Research Committee is still going on under the direction of Dr. Roberts-Austen, and producing work which I can venture to call classical—work which has met with a response on the other side of the Channel by the French, who have established an alloys research committee likewise. But the work of this Committee is carried on at the Mint and at the Royal College of Science, Dr. Roberts-Austen gives his services gratuitously, and I am afraid not only gratuitously, but at some expense to himself. The Mechanical Engineers provide the assistance and the materials and the instruments. But the consequences of this research are, I think, going to produce very valuable results in the practical work of alloys; and I have been deeply disappointed that the state of the ground at Woolwich has prevented my using the instruments, which Dr. Roberts-Austen was kind enough to make for me in order to test the quality of the alloys by the process of watching the cooling curve, and the irregularities in it, which indicate the precise sort of alloy which is necessary for our purposes. The only way we have now of judging whether the materials we buy from the contractors are good, is to buy a certain quantity and to try and make the cartridge cases with them, which is a very unsatisfactory method of proceeding, and one which very few contractors can adopt. By means of cooling curves we should be able to settle the quality of the materials in a much more economical and more scientific manner. That I am afraid cannot be done at the Arsenal, but if any such central laboratory as we are considering is established I should certainly invoke its aid in the purchase of materials, and the contractors also would know exactly what conditions they have to satisfy, which at present are exceedingly vague.

1665. Much of the work conducted by such a research committee, for instance, is not of a kind which is contemplated in the terms of reference to us?—No.

1666. But still is there not much of the work which is done by that Committee which might be entrusted to a national physical laboratory?—I think so, the greater part of it, I think.

1667. And would have been entrusted had there been such a laboratory available?—Yes, had you not been kind enough to have undertaken the work for the Mechanical Engineers you know we should not have done it.

1668. Have you found the results published by such a research committee and by other committees actually useful at the Royal Arsenal?—Yes.

1668*. With regard to the cartridge cases that you mentioned, how do you protect the brass from the action of the atmosphere; are there any precautions taken?—That is another point that we are very ignorant about. There is no doubt that the atmosphere, at any rate the atmosphere of London and Woolwich, has an effect upon the brass. We protect them now by varnishing them—we lacquer them over; but we do not understand exactly how the atmosphere acts upon them.

1669. Take the question of crusher gauges again. It seems to me almost impossible to get any two varieties of copper alike, giving concordant results as regards the velocity of projectiles unless they have been carefully prepared; is it not a question of very great importance?—It is of very great importance. The only way we get over the difficulty is this: we make all the crusher gauges practically. I believe Sir Andrew Noble makes all his own, and we make all our own, and we supply the greater part of our gunmakers with them, but it does not at all follow that they are correct absolutely, though, for purposes of comparison, they may answer fairly well.

1670. (*Sir Andrew Noble.*) You have got to test each lot?—We have got to test each lot with the old ones, but how far we are from the actual truth I do not know.

1671. (*Mr. Roberts-Austen.*) There are many investigations, I gather, that might be considered in the proposed physical laboratory, and which might be undertaken for individuals?—Yes.

1672. They would be remunerative, would they not?—I think so. I think the laboratory might be made self-supporting in a great measure

1673. (*Sir Andrew Noble.*) To a very large extent?—To a very large extent, I think.

1674. (*Mr. Rücker.*) I should like to ask you a question with regard to that point. Supposing the Government Department or the Woolwich Arsenal came to the laboratory with a question of a novel kind, and that the laboratory was already expending all its resources on the work it had in hand, do you think it would be possible for a Government Department necessarily to pay something, at all events, towards the expenses of such a laboratory?—I would pay for the whole of the expense incurred for my department.

1675. You would be willing to pay for the whole of it?—There is no difficulty about paying for anything that we want. What would be difficult to get would be Government sanction for the appointment of a trained experimenter for making experiments; but if it be necessary to make any investigations there never is any hesitation about providing the money for that purpose.

1676. So you think there would be no difficulty in the Government work being from the laboratory point of view largely self-supporting also?—No difficulty at all.

1677. There is another question I think has not been put to you which I should like you to answer; you agree, presumably, that it would require a man of very high scientific position to be at the head of such an institution as the National Physical Laboratory?—I think so, certainly.

1678. Have you formed any idea as to what such a man should command—what salary it would be reasonable to offer?—I think a first rate man of that kind ought to have £2,000 a year. He would have to give up all his time to the work.

1679. You would probably think it extremely desirable that he should give up all his time?—I think so, certainly.

1680. You think something like £2,000 a year would be reasonable?—Yes, I think so.

1681. (*Mr. Roberts-Austen.*) You say that both as a Government officer, and as having managed a large manufacturing business?—Yes.

1682. (*Sir John Wolfe Barry.*) If the Government sent a matter to be investigated at the National Physical Laboratory I suppose the results would be imparted to the public?—That would depend, you know.

1683. That might, or might not be?—Yes.

1684. So far as Government investigations were concerned it would be proper and right, perhaps, that one Department should pay for their work, and to that extent the Physical Laboratory might be self-supporting; but supposing private individuals invoked Government aid to determine a problem, would you allow that to be kept secret?—I should think it ought to be secret, if required, somewhat on the same principle that a patent is kept confidential during the time which elapses between the sending in of the provisional and the acceptance of the complete specification. I think there ought to be the possibility of doing that.

1685. But supposing there were objections to its being kept secret, and the results were published in the Report of the Committee of the National Physical Laboratory, then all that was done would be public property, and in that way it might be difficult to get any repayment for an investigation?—Do you mean if everything was published?

1686. Yes, if everything was published?—I fancy the number of cases where private individuals would want to keep the results secret would be very few, and could easily be made the subject of a preliminary agreement.

1687. But supposing they are made public, you think they would still be willing to pay for the investigations?—I think so, if they got the information they wanted.

1688. (*Sir Andrew Noble.*) In the large majority of cases the subject of the investigation would probably be patented under the circumstances you are considering, and in that case there is no objection to its being published if it could be covered by a patent?—No, but I think there ought to be the possibility of carrying out investigations at the instance of the person who wishes them carried out, so that he alone should have the advantage of the knowledge obtained, at any rate for a limited time.

1689. (*Sir John Wolfe Barry.*) Does not that seem to you to be rather a matter which should be investigated by a private laboratory?—If it can be done.

1690. Rather than a public laboratory?—If it can be done.

1691. The justification for employing public money is that whatever is found out should be public property?—I assume that he pays the full expense of carrying out the investigations.

1692. He might be at that time ousting some other work which would be of public interest?—Of course, in that case it could not be undertaken.

1693. The primary object, no doubt, of a public institution would be to get information which would be valuable to the whole commercial world?—Yes, but you see a

man may be bringing out some new invention in metallurgy, we will say, and he wants certain experiments made, but these experiments will not bear fruit for a couple of years. While he is arranging his plans and making his investigations, he might wish to keep the thing secret until he was ready to divulge it. For instance, during the time which lapses between the application for a patent and the granting of it.

1694. But there are other laboratories where he could pursue these investigations?—Yes, I suppose there are; it depends upon what sort of instruments you want.

1695. There is a Davy-Faraday Laboratory, for example?—That is chemical. But when you come to metallurgical processes requiring costly apparatus, or experiments under pressure or very high temperature, and things of that sort, you would not find many sufficiently equipped.

1696. It is a very important question whether we are to hope that a National Physical Laboratory of this kind would be self-supporting, or whether we are to consider that, assuming it is a good thing in itself, that it justifies its existence quite independently of whether or not it is self-supporting?—Yes, I think, as I said before, that there would be very few cases where any secrecy is required.

1697. You think to some extent it might be self-supporting?—Yes, I think it would be very largely self-supporting.

1698. Of course, I am not talking at all at this moment of standardising—I think that is quite another matter; I am talking of research into the properties of matter?—Yes, I understand. You see, when a private manufacturer undertakes research of any kind, it is an unknown expense to him, really; he does not know what it is going to run him to, how many people would have to be employed about it, how much material would be required; then there would be his own time that he would give to the research which might be more profitably employed elsewhere. I am quite certain that a great many manufacturers, if they knew that there was a trustworthy laboratory in which the research could be carried out would very much prefer to have it done for them.

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1699. You think they would prefer to have it quite apart from keeping the result a trade secret?—Yes.

1700. Therefore, you think that an application of public money in this direction would be for the good of the whole community?—I am quite sure of that. There is an immense number of cases where you require contractors to do things, and they have no means of ascertaining or knowing whether they are on the right way or not until they deliver the article.

1701. Your wants at the Royal Arsenal could not be met by your having a Government Laboratory inside the gates, because that would not be accepted in the same way as an impartial National Physical Laboratory?—No. For instance, take our proof butts, where cordite is proved, and shot and shell, and all that sort of thing—it is administered by artillery officers, very excellent officers no doubt, but being a good artillery officer does not necessarily make a man a good experimenter. You have delicate instruments to handle, and very often the results obtained by gunmakers or contractors, who have just as skilful experimenters as we have, are not concordant with ours.

Wednesday, 9th February, 1898.

PRESENT:

Mr. A. W. RÜCKER, D.SC., F.R.S. (in the Chair).

Sir COURTENAY BOYLE, K.C.B.
Sir ANDREW NOBLE, K.C.B., F.R.S.
Sir JOHN WOLFE BARRY, K.C.B., F.R.S.
Mr. W. C. ROBERTS-AUSTEN, C.B., F.R.S.
Mr. ALEXANDER SIEMENS.
Dr. T. E. THORPE, F.R.S.

Mr. L. BLAIKIE, *Secretary*.

Mr. WILLIAM HENRY MAW, called; and Examined.

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1702. (*Mr. Rücker.*) You are one of the members of the Institution of Mechanical Engineers?—I am a Vice-President.

1703. Have you given any special attention to the desirability of establishing a National Physical Laboratory?—Generally speaking, yes. The matter has come before me both at the Institution of Mechanical Engineers and in connection with the Royal Astronomical Society. The Royal Astronomical Society had a circular sent to them the same as the Institution of Mechanical Engineers, and the matter first came under my notice there as a member of the Council of the former Society.

1704. Therefore you can speak from two points of view, for the Mechanical Engineers and the Astronomical Society?—Yes; but I attend here on behalf of the Institution of Mechanical Engineers.

1705. Have you formed any opinion whether it is desirable that such an institution should be established, speaking generally in the first instance?—I have a difficulty in answering that question. In the circular I have seen no very distinct description is given of what the institution may consist of; and it is very difficult to form any opinion, and one would require more definite information as to what the scope of the institution may be.

1706. Take the first object of the Inquiry as to the testing and verification of instruments for physical investigation. What instruments for physical investigation do you think should be included on that head; do you think that anything can be done for the Mechanical Engineers?—I do not think that anything can be done for the mechanical engineers in that way.

1707. Do you think that the instruments that they may use are sufficiently standardised and verified already?—Yes, for the practical use of Engineers.

1708. Take steam gauges for instance; are they standardised by any expert body at present?—No, they are standardised chiefly by the makers, and in the case of the large users like the Railway Companies, they are standardised by the users themselves. The Railway Companies test their own gauges, and many of the steamship companies and other large users do so likewise, but the Railway Companies in particular have their own standards.

1709. Do you think there is any use in having an independent body, to whom such things as chronometers, which are at present tested at Kew, could be submitted?—I think not. I think, for instance, steam gauges which you mentioned are sufficiently accurately tested by the makers; at any rate they are accurate within the limits of practical use.

1710. You would be ready to trust to the makers only?—Yes, I would trust to the makers only.

1711. Take another case, which has been mentioned by one of the witnesses, the case of condensed gases, in which public safety is involved; do you think that an independent test should be made of the cylinders in which those gases are stored?—Do you mean as a mechanical engineer, or as a general user of gas cylinders?

1712. Speaking generally?—I do not think that any public body would be of any use, say, to those users who have their cylinders filled by the Brin Oxygen Company.

1713. As a matter of fact at present there is no test except that of the makers?—Except that of the fillers; they are not the makers of the cylinders. There are tests by the makers of the cylinders, but they are not quite sufficient in themselves, because a cylinder might deteriorate or become damaged by accident. You want provision to be made for the periodical testing of the cylinders, and that you can get done by the Brin Company, or the companies associated with them. In the case of such cylinders it is more a case of the makers and the users of the cylinders availing themselves of the means of testing now existing, than of introducing new means. That is the difficulty.

1714. May we generalise that proposition. Do you think in general that the tests carried on by makers are sufficient guarantees in matters of that sort?—In the case of gas cylinders the tests made by good makers are sufficient for the initial condition of the cylinders, but not for their permanent condition. They have to be

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supplemented as in the case of boilers by periodical testing.

1715. Do you include electrical engineering in the matters on which you are prepared to speak?—No, I do not.

1716. You express no opinion upon that?—I have an opinion upon that, but I would rather not give it. Professor Kennedy, who has been appointed as my colleague in representing the Institution of Mechanical Engineers, has had a large practical experience of that, and you had better take his opinion.

1717. In the case of the construction and preservation of standards of measurements, are there any points where a Physical Laboratory would be useful?—Not for mechanical engineers.

1718. Is it true that many operations in mechanical engineering involve the subjecting of the apparatus to very high temperatures, take steam boilers for instance?—Not necessarily in steam boilers.

1719. They are not excessively high, but in other cases they are much higher?—That is rather a metallurgical question; it is not purely engineering.

1720. You would rule high temperatures as being outside your reference?—Yes.

1721. Then what have you got to say about the systematic determination of physical constants and numerical data useful for scientific and industrial purposes. Do you think that anything could be done by a National Physical Laboratory in that way?—That is a very difficult question to answer. You never know where a physical constant might come in useful. I do not know of any particular constants that at present require verification for the mechanical engineer, but the case might arise any day—you never know.

1722. But the Mechanical Engineers have appointed research committees on physical constants?—Yes; but they have rather different objects in view. They have had a series of research committees, and I have got a list of them here.

14 Dec., 1897.

INSTITUTION OF MECHANICAL ENGINEERS.

Research Committees.	Appointment.	Expenditure.		
		£	*s.*	*d.*
Best Form of Riveted Joints.	Feb., 1879	597	2	2
Hardening, &c., of Steel	Feb., 1879	154	2	11
Friction at High Velocities.	Feb., 1879	555	9	1
Value of Steam Jackets	Sept., 1886	392	2	9
Marine Engine Trials -	Dec., 1886	1,131	1	5
Alloys Research - -	Oct., 1889	1,160	15	7
Rope and Belt Driving	Feb., 1894	97	15	10
Working of Gas Engines	Oct., 1895	135	13	0
Steam Engine Research	Oct., 1895	150	0	0 (Voted)
	£	4,374	2	9

I do not know whether it has been put before the Committee before, but I think Sir William Anderson brought the matter forward. I am not quite certain whether he put in the list, or not. I think the Committees have had rather a different scope from the work contemplated by the National Physical Laboratory. The first one was appointed in 1879, on the "Best Form of Riveted Joints." I take it that that is not a line of investigation that would come under the Laboratory proposal.

1723. You think it is too technical?—Yes, and it requiries appliances which you would not expect any such laboratory to be fitted with: it would be very expensive to provide these appliances purely for this line of research. The next Committee is on the "Hardening, etc., of Steel." That is one in which I think this Laboratory, if established, probably might assist materially in combining what I may call the metallurgical aspect of the question, and the mechanical aspect of the question. The next Committee is that on "Friction at High Velocities"; that is a research which could be better investigated by the Institution of Mechanical Engineers than at a National Laboratory. The next Committee is on the "Value of Steam Jackets"; that is a purely mechanical engineering question. It is an inquiry that could not be carried out at a Laboratory. You would have to carry out experiments with actual engines, and with a variety of engines which you could not have at a Laboratory. The next Committee is that on "Marine-Engine Trials." That is quite outside of your line. The next is the Committee on "Alloys Research," with which Professor Roberts-Austen is very largely associated. That—like the second Committee on the Hardening of Steel—might very probably receive assistance by your Laboratory. It involves the pyrometer question that you raised just now, and there is a mixture of physical and mechanical questions involved which might be very well dealt with at the Laboratory. The next Committee is on "Rope and Belt Driving." That is a subject you could not deal with at the Laboratory at all. The next Committee is the "Working of Gas Engines." That is a new Committee, which has been only just started; it was established in 1895, but for certain reasons it only actually commenced work a few months ago. I have the first Report in my pocket now. That is a research of a purely engineering character. The last Committee is on "Steam-Engine Research." That comes under the same category as the gas engines.

1724. May I ask where the work connected with the alloys research is carried out?—Chiefly at the Mint, under Professor Roberts-Austen.

(*Mr. Roberts-Austen.*) And at South Kensington, at the Royal College of Science.

(*Mr. Rücker.*) You have not a place of your own, where such things could be carried out?

(*Witness.*) No.

1725. Do you think it entirely satisfactory that investigations of this sort should be carried on in Government Institutions, which are not primarily intended for this work?—That is a question which Professor Roberts-Austen could answer better than anyone. It is, I think, merely a matter of arrangement. I think that the researches may be useful to the Government Institutions as well as to mechanical engineers.

1726. Supposing the constitution of the proposed Institution were sufficiently flexible to allow of experts being introduced on to the Committees which have charge of the particular investigations; do you not think that the fact that such a Committee could readily be formed for such an investigation would be very useful?—Yes, I think so. There are certain lines of research that might be carried out, as I said before, but not purely mechanical engineering researches.

1727. But there are scientific questions which bear upon mechanical engineering, in which such Committees might be useful?—Yes, indirectly.

1728. We have had the evidence of Lord Kelvin in which he says that a good deal might be done on the effect of long-continued vibrations upon the strength of materials. Is that an investigation which could be carried out usefully by such an Institution?—I doubt whether it could be more usefully carried out by a laboratory than it could be by people directly interested in the facts. For instance, the railway companies could carry out the investigation quite as well, and, probably, more quickly than the Laboratory.

1729. Then it would be for their own purpose only?—The results would be communicated to some Scientific Society.

1730. Do you think they would?—Yes, there is no secrecy about such matters.

1731. Then you are of opinion that, in the case of an investigation which would take years to complete, that a great industrial railway company would devote itself to work of that sort?—I think they would. I know that our large railway companies, such, for instance, as the London and North-Western Company, if they felt the necessity of an investigation of that kind, would not hesitate a moment to carry it out, but they have to feel the necessity. I should like to say that this little document about research committees, which I have handed in, gives the sums devoted by the Institution of Mechanical Engineers for those various researches; but the amounts do not at all represent the total cost of those researches. For instance, all the printing of the Reports, and anything of that kind, was done in the ordinary way by the Institution, and it was not charged to the Research Committees; and then, of course, the time given to the work was given to it by the members of the Committees gratuitously.

1732. (*Sir Andrew Noble.*) Of course, you will understand that the object of a Laboratory of the description that our Chairman has been mentioning to you is intended to supplement private research, or research by such bodies as you have named, and the railway companies. I suppose you would think it a matter of considerable importance that we should know the effect of secular stress upon the strength of materials?—Quite so.

1733. Is there any such investigation being carried on at present?—There are the old experiments of Wöhler, which cover a very considerable ground. Since these were carried out, we have had many improvements in the manufacture of steel; and the classes of material available now are not quite those with which the experiments were made.

1734. Hence you would agree that it is important to engineers, and, therefore, of importance to the country, that the effect of secular stress upon materials should be known?—Quite so; I agree.

1735. But would you not also agree that such a series of experiments would be best carried out by such a body, if I might call it so, as our Chairman has named to you?—That would depend upon the means for putting that body in motion. Take, for instance, that a particular class of manufacturers feel the want of information such as you have just named.

1736. I may say, at once, that they do; at least, I answer for the branch of it I know?—Well, unless they had the means of getting the Laboratory to take up the work and carry it right forward without delay, would it not be better for the manufacturers to carry it out themselves?

1737. For the particular manufacturer, perhaps; but the particular manufacturer, if he were carrying on an investigation extending over long periods of time, and involving considerable expense, to gain scientific knowledge, he would, as far as my experience goes, be inclined to keep that knowledge to himself. Now the effect of an investigation, at a Physical Laboratory, such as we are contemplating, would be that it would be known to the whole country, both at the conclusion of the research, and, even, probably, during the continuation of it, so that the country would have the advantage of it immediately. I think one can hardly deny, supposing such a research were carried out by the Physical Laboratory, that it would be of very great benefit to the engineering trade generally, would it not?—I think the knowledge obtained from the investigation you speak of would undoubtedly be of benefit to the engineering trade generally, however it was carried out.

1738. I may say that there are various other researches that it seems to me could also be carried on, such as that mentioned by Professor Rücker, as to the effect of continued vibration; the effect also of putting on suddenly and taking off during stress through a long series of time; also the effect of heating and cooling rapidly—all these, it seems to me, are of importance to engineers. It also seems to me that it would be nowhere so well carried on as in a Physical Laboratory, and the results would be of value to the country?—When you are speaking of the effects of vibration, do you mean particularly on bridge structures, or structures of that kind?

1739. Take bridge structures, or, as one of our witnesses put it, the crystallization of rails due to vibration, upon which matter I had better leave you in the hands of Sir John Wolfe Barry; but, anyhow, giving that general term to it, you will admit that such investigations would be useful to the engineering trade generally?—Quite so. I certainly admit that.

1740. Then, there is also the question that you have yourself touched upon, namely, the question of alloys. Surely the various physical facts connected with them are of immense importance to us: would they not also be of immense importance to the engineering trade generally?—Yes, I think so. The subject would not have been taken up by the Institution of Mechanical Engineers unless they thought it of importance.

1740.* The question was, whether it could be better done by the Laboratory than by private enterprise?—Well, that is more a question of means, and we have been very fortunate in that respect.

1741. I leave Professor Roberts-Austen to question you upon that point; but I will mention one thing that seems to me of very considerable importance: you are aware that tubulous boilers have come very much to the front just now?—Quite so.

1742. Would it not be a matter of great importance to engineers if you could discover an alloy for these tubes, that is giving very little scaling at high heats?—Yes.

1743. And also an alloy with a co-efficient of expansion under heat as small as possible—that, also, is a very important point to engineers as regards boiler tubes, is it not?—Yes.

1744. Would not an investigation of that nature be carried on more effectually and more for the good of the community at large, if it were done by a Physical Laboratory such as we are contemplating?—I think that would depend upon whether the Physical Laboratory was in thorough touch with the ultimate users of the materials, so that the investigation might be decided in a practical way.

1745. You must give us credit for seeing that it is. But on the assumption that you have yourself made, that the governing body of such an Institution is thoroughly in touch with the engineering wants of the country, would it not, then, by such a body, be carried out for the good of the country better than if it were left to private investigation?—If by "private investigations" are meant investigations carried on by some Engineering Institutions, I should be rather inclined to say no. If, however, investigations of the kind you mention were carried out by private firms, they would probably be carried on by makers largely interested in the class of boilers used, and the results would be made the subject of patents.

1746. But you cannot be the worse for having on your governing body, while seeing you have men full conversant with the technical side of the question, men also who are purely scientific?—Quite so. The Institution of Mechanical Engineers always put purely scientific men on their committees along with the mechanical engineers, and if your Laboratory had equal chances of choosing the men for carrying out the investigations there would not be much to choose between the results of the two Committees. It comes very much to the same thing, and then it becomes merely a question whether the Institution or the Laboratory could expend the greater sum on the investigations. If you have the same kind of men on both committees there is no reason why the results should not be the same.

1747. But private manufacturers, however good they may be (and the Mechanical Engineers are chiefly composed of private manufacturers), have their business to attend to, have they not?—Yes.

1748. They cannot devote that time and attention to researches, extending over long periods of time, which a body such as we are contemplating could do?—I am not quite so sure about that. The body you are contemplating, unless a very large body indeed, could personally devote comparatively little time to each of those researches. There are a very large number of researches to be carried out. The interests of mechanical engineers form only one set of interests, and unless the acting managers of this Laboratory were a very numerous body indeed, they would be able to devote comparatively little time to each of the investigations taken up, and they would be very much in the same position as the members of the Institution of Mechanical Engineers are.

1749. I hardly think so. But coming to the question of standards. I rather understood you to say, I am not quite sure that I did understand you properly, that you thought there was no necessity among the Mechanical Engineers for obtaining standards or getting records of measurements for example?—I meant to convey that the standards available for the use of mechanical engineers are quite sufficiently accurate for all practical requirements. If you give an order to four or five different firms to make things of a certain size, you will get the articles supplied by those people all uniform within the limits of practical requirements.

1750. It depends how far you go. I am bound to say that is not my experience. I will take a dimension measured in two establishments to the thousandth of an inch; if that went through various Mechanical Engineers, would it be the same measurement?—If you are going to work to the thousandth of an inch you have to select your firms; it would not do to go to anybody; but if you select your firms I think you could get what you want.

1751. I have some doubt about it. I will take, for example, the Government Establishments. I have known the same dimension measured at one of the Government Establishments, and measured (I will call it by the Whitworth Company) vary by a couple of thousandths of an inch. Now, of course, I am perfectly aware that supposing, for example, you sent a point gauge to the two places, and it differed by that amount, there may be a great deal of personal error in it: but would it not be an advantage if you had an authority to which you could go and say, "Give us the dimension of that gauge?"—In the case you have mentioned a large part of an error probably arose quite as much in working to the gauge as in the error of the gauge itself. I think that a more absolutely accurate gauge would not affect the question.

1752. Yes, but you would have only one person to refer to, who would do it in the same way. We have had it in evidence that the personal error affects it quite as much as the actual measurement. But still, you want some place where you can go to to get that fact settled if there is a dispute about it. You have yourself, to a certain extent, answered the question by saying that there are only a few firms you can go to?—Quite so.

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1753. We are anxious to see that all the firms in the country, if possible, when they say such a thing is an inch, that they would give you an inch?—I do not think that is necessary in a large number of cases.

1754. Quite true; but the more accurate the better, you must admit that?—In some cases I do not think that it is better, practically.

1755. In a good deal of Government work they say there is to be no error at all. I think that is a little absurd, because you must define what you mean by "no error." But in certain Government contracts you will find they put in "no error at all;" and there are no limits allowed of plus and minus thousandths; and there are constant disputes as to the dimensions when the work is done in different establishments from that of the Government?—But I am obliged to answer you in the form of a question: Do you mean errors of reading the gauges—working to the gauges—rather than errors in the gauges?

1756. It is partly the one and partly the other. There are a great many micrometers that are not at all points of the scale perfectly accurate?—Quite so.

1757. I need not say that the temperature affects the micrometer. I think myself, as a manufacturer, that there should be some place where the manufacturer can send his micrometer to be verified, and in the case of a disputed measurement, he can get it measured by authority; do you agree with that?—I do not see the necessity for it. I think that if a manufacturer now wants to verify his measurements he can do it. The errors that exist at present arise chiefly from two causes; one is what I might call the faulty use of the gauges, and the other is not taking the trouble to get the gauges verified. I do not think it arises from difficulty in getting the gauges verified, it is due to not getting the verification made.

1758. Where would you get them verified?—If they came from the Government I would get them verified by the Government. I should compare them with the Government gauges.

1759. You cannot do that—what or where is the Government gauge?—I presume that by which the accuracy of the work is eventually ascertained.

1760. If you could send your point gauge to them, and then you said, What is the dimension of that point gauge, then you could have your answer at once, and it could not be disputed?—You have to make the Government accept that statement.

1761. Do you mean the standard gauge of the Board of Trade?—No, I mean in the case you are speaking of. I presume you are speaking of orders given out, probably by the War Office or the Admiralty; you will have to take the Admiralty or the War Office gauge as the standard in the case of work done for those departments.

1762. (*Sir Courtenay Boyle.*) How would the War Office or the Admiralty get their gauge verified?—I do not know how they would get it verified now. Originally, I presume, it would be by the standard yard.

1763. By whom?—By their own officers, I presume, but I do not know.

1764. Is not there a standardising officer?—I presume that any private individual could get his gauges verified in the same way as the War Office get theirs.

1765. If there were an establishment such as we are contemplating, the point gauge, which is generally the means of measuring, could be sent to the standardising officer, and he would say what it is?—Quite so.

1766. If there be such a difficulty as I have described, would it not be for the advantage of the country that there should be a standardising officer, who is capable of saying what the dimension in dispute is?—Certainly, I quite agree with that.

1767. (*Sir Andrew Noble.*) Now, I venture to take you to a question of considerable importance, the question of screws. You know, of course, I suppose, that the only screws that we can call standards in this country, are the Whitworth screws?—Quite so—you are speaking now for anything above a quarter of an inch.

1768. I am speaking of the whole series?—Down below you get to another series.

1769. Whitworth has a series a good way down, but he also has a second series to the millimetre or the metre scale, in the metrical scale?—I did not know that.

1770. But quite recently the French Government have pointed out generally the inconvenience of having various systems of screws in France?—Yes. I know that.

1771. And they have introduced a new system, have they not?—I am aware of that.

1772. It does not differ very much from the Whitworth, except in the pitch, especially in the lower screws, and in the form of the thread?—And in the angle; they have taken the American angle of 60deg.

1773. In the form of the thread I include the angle. As far as I remember at this moment it is an equilateral-triangular pitch with $\frac{1}{8}$ cut off the top and bottom, or something of that sort?—That is so.

1774. It would be very advantageous to those who have to do foreign work, I suppose, if we could have the power of comparing with the French standards at some establishment in this country, even if we do not have a standard of our own?—Quite so.

1775. And I suppose you would also add that it would be very advantageous if we could get the Government to introduce a standard series of screws right through that could be followed in the country generally?—Do you mean in place of Whitworth?

1776. I do not say in place of it; they might take what they please for that matter, but at present they do not recognise solely the Whitworth screw, and they have other screws in use, too, and other forms of thread?—Yes, for large screws, but my impression is that for what we may call moderate sizes, up to about three inches, they use the Whitworth.

1777. I do not think that at this moment it is specified that anybody is obliged to use a certain screw in Government work, or, I should say, a certain standard of screws?—I cannot answer that positively, but I believe that in the Admiralty contracts the Whitworth is specified.

1778. It is not invariably?—I should not like to make it as a statement, but my impression is that it is so for all sizes up to about $2\frac{1}{2}$ or 3 inches.

1779. At all events you would agree that it is important that the Government should establish a system of screws?—I think it would be a very judicious thing to do, as long as they adopted the Whitworth, because that thread is so largely bound up at present with mechanical engineering practice that a change from that would be very disastrous, I mean, so long as we retain the inch or the foot as our standard or unit. If we adopted the metric system then I think we had better adopt a screw which has already been adopted by a metric country.

1780. That is the reason why I mentioned the French system—because it is a metric system?—The French Admiralty screw, I think it is generally known as.

1781. Yes, it is known as that. The only screw that I know of as an international screw is a microscope screw, is that so?—That is so.

1782. Coming to the other question that you touched upon, the question of the constants, I suppose you would admit that it is of great importance to know the secular changes in the co-efficients, for example, of elasticity?—I think so.

1783. And also in the thermal co-efficients?—Quite so; for physical reasons I think it is very important, but I do not think those secular changes have much effect on what I may call ordinary mechanical engineering practice; from the physical point of view I think they are extremely important and interesting.

1784. I think the Chairman asked you two questions, which I intended to ask. I wanted to ask you if you would not consider it desirable, in reference to the testing of steam gauges, that users should have the power of sending both their steam gauges and their steam indicators to a body like the National Physical Laboratory that we are speaking about?—I think in the case of steam gauges, as I said before, that they can be tested by the existing means with quite sufficient accuracy for all practical requirements. A steam gauge does not retain its accuracy for any length of time—no steam gauge that I know of does.

1785. Is that not a reason why the user should have the power of sending it periodically, if he likes, to a laboratory to be tested, and get a certificate—the user of a steam gauge may be comparatively ignorant about it?—Yes, he may.

1786. But if he gets a certificate that it is all right?—He can get that now from any steam-gauge maker of experience.

1787. He can get it, but I do not admit that every steam-gauge maker works to the same degree of accuracy that I would expect this Laboratory to work to?—No, but I think he works within the limits of practical requirements; I mean that with an ordinary gauge for a boiler working, say, at 120 pounds to the square inch, you might try a hundred gauges from different makers, and if they were good makers, they would not vary half a pound. It is astonishing how little they do vary—even the cheap gauges when new—at about the working pressure. I do not know whether the question was put to Sir William Anderson. He has had a very large experience in testing these gauges at the agricultural shows. The whole of the gauges on the show ground are tested by the consulting engineers to the Royal Agricultural Society before they are allowed to be used. Perhaps I ought not to have suggested it, but I

think he could give some evidence as to their experience in that matter.

1788. I think his evidence was rather in favour of having them tested by a body such as we are discussing. There is one other question I want to ask you about. The galvanic action between metals in contact is to engineers of very considerable importance, and I think we may say that we know very little about it?—That is so.

1789. Is not that a subject which could be referred to a Physical Laboratory with great advantage?—I think that is a subject that the Laboratory could take up very well indeed. I do not know that it is a subject of very great importance to what I should call strictly mechanical engineers; it is more important, perhaps, to shipbuilders.

1790. One of the cases that was given, I think, was the breaking off of a propeller blade, and sometimes the breaking of a shaft; surely that is a mechanical engineer's work?—That particular work is undoubtedly of interest to marine engineers.

1791. Then I think Lord Kelvin gave us an instance of the effect of the atmosphere, especially in contact with metal—upon brass, for instance; I think he told us that a coil of brass hung upon a nail after the lapse of some years was found to have become as brittle as pipeclay—I think that was the phrase he used—and he added that although we knew something about it, it was very desirable we should know more?—Quite so.

1792. I was going to refer to pyrometers. Is it not very desirable, as pyrometers now enter very largely into engineering establishments, that we should be able to have them checked from time to time, especially as with use they are very apt to alter?—Yes, and I said before that pyrometers were instruments which I thought could very well be calibrated in such an institution.

1793. Then I think I will not trouble you with any more questions, because you rather prefer, I understand, not to be asked upon electrical questions?—I would rather not, as anything I might say would be more or less from an outside point of view.

1794. (*Sir John Wolfe Barry.*) Sir Andrew Noble has covered a great deal of the ground of the questions that I was going to ask you. I should like to know whether you are aware of the importance of the question of the fatigue of metals in relation to railway rails?—Yes, I am.

1795. I suppose that is a matter which is of the greatest and highest importance to the railway world in general?—Undoubtedly so.

1796. Another matter which is of some importance is the failure of crank axles, is it not?—Yes.

1797. Do you happen to know how many crank axles are returned on the North-Western, as either in danger of breaking or broken in the year?—No, but I could run it out for you.

1798. It is a very large number, is it not?—Yes, it would be about one for every ten engines, I should think, roughly, but I would rather you did not take that as an absolute statement.

1799. I have been told, I do not know whether it is true, that it is one a day?—That would be about the number I have just stated roughly.

1800. That is one a day, which is either accepted as, or found to be, defective?—They have over 3,000 engines, I believe, at the present time, and one in ten per annum would be about 300 a year, and that would be about one a day.

1801. I suppose we may assume that on the other railways it is something like the same proportion?—Quite so.

1802. I suppose we may also assume that those defects are greatly due to the fatigue of metals in the reciprocating parts of the engine?—Yes. If you eliminate the very few cases in which there are flaws—and they are a very small number—I think you may say the whole of the rest are due to fatigue.

1803. Do you know whether any of the railway companies have ever instituted a series of exhaustive experiments on the question of the fatigue of metals?—No, not directly. They have recorded the failures of axles, and the manner in which such failures occur, and in that way they have assumed that an axle which is sound to begin with will stand a certain number of miles' work without any great chance of failure. Some railways take them out after they have run that number of miles without running the risk of using them any longer, and do not employ them for further service unless they successfully pass a very rigorous examination.

1804. That is rather a rule of thumb than a scientific method?—I should not call it a rule of thumb; it is a rough way of utilising the results of experience.

1805. I think you said you thought that when matters were of importance one might rely upon the great railway companies investigating them scientifically?—Yes, and they have to that extent; they have eliminated the chances of their accidents by stopping the axles after they have run a time when they think it would be dangerous to continue. The axles are, moreover, subject to very rigid inspection during their working life.

1806. But they have not instituted a series of scientific investigations on the subject?—No.

1807. Although it is a matter of great importance?—Because they have not felt the necessity of it, and they think, and I consider rightly, that their present practice covers the ground.

1808. Does it seem to you that that is the way in which a great subject of this sort should be approached?—From the railway point of view, I say yes.

1809. But you cannot rely upon a railway company to investigate the subject exhaustively?—Not beyond their own requirements, but within their requirements, yes.

1810. Practically, therefore, one may say that people who are interested in these things do not go beyond their own requirements, and really do not bottom the subject at all?—No, that is so.

1811. You told us of the very important and interesting investigations made by the Institution of Mechanical Engineers; how much has been spent by them in those investigations?—The sum voted, as given by the paper which I have handed in, is £4,374.

1812. And that has been spread over how many years?—It originated with the Riveted Joints Committee in 1879; then there was a long gap between 1879 and 1886, when practically very little was done, and then the work was resumed in 1886.

1813. Have you put in a paper showing that?—I have put in a statement of the expenditure on the different committees. As I stated before, that is merely a statement of the sums voted to the different committees, and it does not represent the total expense of the inquiries.

1814. It does not represent the large amount of gratuitous work given by the members of the committee, does it?—That is so, nor does it represent also the gratuitous facilities offered by people whose engines have been tested. For instance, in the case of the Marine Research Committee we have had the use of steamers on certain days, and the coal and everything has been provided by the owners. That would have been a very large item indeed if the Institution had had to pay for it. Many of these marine engine research experiments would have cost probably £200 or £300 for what was given to the Institution gratuitously.

1815. At some time in the history of the Institution of Mechanical Engineers the need for these investigations was realised, then?—Quite so.

1816. Do you think the need is any less now?—No, I think the number of things to be taken up is increasing every year. Take the case of those fatigue experiments you touched on just now. I think that one matter which was neglected in the earlier experiments was the connection between what we may call the mechanical results and the chemical structure of the steel; steel was taken as steel, and no account was taken of its analysis.

1816*. When the Mechanical Engineers have arrived at certain results, I suppose they are published in their proceedings?—Yes. Perhaps I might state how the committees are worked.

1817. Do, if you please?—First of all the council have brought before them certain subjects which it is thought might be investigated. They select one, and a small committee is formed. This committee meets, elects its chairman, and then it generally adds to its number by electing other members on the committee. Then a brief preliminary report is made to the council, and a grant asked for for certain objects. Then the committee gets to work. After they have obtained some results those results are embodied in a report, which is read at a meeting as a paper and discussed. That usually brings out from the members generally a demand for information on certain points, and those points are taken up in the continuation of the investigation. In many cases—in Professor Roberts-Austen's Committee, for instance—there have been a series of these reports which have been discussed at the meetings.

1818. How are they published?—They are published in the "Proceedings," and they are published in the technical journals.

1819. Their publication is not confined to the "Proceedings," then?—Not at all; they are published in the technical journals, together with the discussions, before they appear in the "Proceedings," as a rule.

1820. I think you said that gas cylinders also showed signs of fatigue or deterioration?—I think it is deterioration by damage; I do not think it is fatigue in their case; sometimes it is corrosion.

Mr. W. H. Maw.
9 Feb. 1898.

1821. Supposing I had two or three of those gas cylinders working, what would be my course under the present regime for finding out whether they were right or wrong?—If you had them filled by the Brin's Oxygen Company, or by the associated companies, you need take no precautions at all, because they simply will not fill a cylinder that has not been tested within the year. They test every cylinder when it goes into their place for the first time; they stamp it, and register the date and everything else. If that cylinder comes back to them to be refilled during the year they refill it at once. If it comes back to them on the first day of the next year, even if they have tested it on the 1st of December in the previous year, they do not fill it until it has been re-tested.

1822. They re-test, then, yearly?—They re-test the cylinders in every year. They draw a hard and fast line on the 31st December.

1823. The question of alloys I think Professor Roberts-Austen will probably discuss with you, and therefore I will not touch upon it, except to say that I suppose everybody will admit that one of the most pressing questions nowadays is what can be got out of metals with alloys under different conditions?—Yes, that is an exceedingly important thing.

1824. (*Sir Courtenay Boyle.*) With reference to crank axles, the present rule of the railway companies is to remove an axle after so many miles have been run, is it not?—That is so in some cases.

1825. But in fixing the number of miles which governs their procedure they have been guided purely by experience, and not by any scientific knowledge?—No, by experience.

1826. In other words, they have simply been guided by accidental occurrences, and not by any scientific investigation of what duration of strain an axle can stand?—Yes.

1827. They have simply been guided by the occurrence of accidents?—That is so. It would be very difficult to follow any other course in the case of a crank axle.

1828. Is it not desirable that the great railway companies in framing a rule for the withdrawal of their axles should be guided by scientific examination rather than by pure practical experience?—No, I do not think so. I think that the experience on which they found their present rule is a better guide than any series of experiments would be.

1829. Supposing they suddenly found some axles failed short of the mileage which they had fixed, would they not have to alter their procedure altogether?—That would depend on what the failure was due to. If it were due to bad material they would have no reason to alter their practice on that account; but if it were due to additional weights being put on, or higher speeds, or something of that kind, then they would have to alter their practice.

1830. Do they know anything really scientifically about the behaviour of metal under strees?—I think so.

1831. Is not their practice grounded purely on the absence of the happening of accidents?—I do not quite see how the strains to which an ordinary crank axle is subjected could be imitated in any form of testing machine—I put it in that way.

1832. Is it not possible to conduct scientific experiments that would show the power of resistance to stress which a particular metal in a particular shape would have?—Quite so. But then we should not know whether that stress was a stress which an axle met with in ordinary practice.

1833. But would it not help the railway companies in framing a rule to know what the scientific factors were?—I do not think so.

1834. To go to a different subject. As regards copper tubes on ships' engines, are you aware that there has been a movement lately to substitute copper for steel in the tubing of ships' engines?—Do you mean tubes for boilers, or for condensers, or do you mean for steam pipes?

1835. For steam pipes?—I am aware of that.

1836. Is there any body or department of the State to which either a firm interested in these copper pipes or a shipowner who did not know whether copper pipes were good or bad, could turn for information; is there any standardising department of the State, or anything else, capable of testing those copper pipes?—The only way of testing them is by hydraulic pressure, which any marine engineer can apply.

1837. By whom?—By himself; they are so tested always.

1838. The marine engineer is very often interested in the supply of the pipes, is he not?—He is a great deal more interested in their standing than he is in passing a defective pipe.

1839. The firm which supplies the pipes are particularly interested in the supply of pipes, and might stoutly contend that the copper pipes are capable of standing any strains?—I should not think that.

1840. Except the Court of Survey, what appeal is there in any such case?—The pipes supplied to any firm of engineers, of any standing whatever, are always tested before they are put into a ship.

1841. By whom?—By the makers of the engines.

1842. Under what circumstances are they tested?—By hydraulic pressure.

1843. Is that a sufficient test?—Quite. I do not know of any other that you could apply.

1844. Is that a sufficient test of the behaviour of copper pipes on a voyage?—Yes, I think so.

1845. That is your answer to that question?—Quite so.

1846. Is it not desirable that the marine engineers on the one side, the shipbuilders on the second side, and the producers of copper-tubing on the third, should have a department, or a body, or a society, to whom they could apply for an authoritative test of the efficacy and efficiency of these tubes?—I think not. I do not think it can be done better than it is done now. Any steamship owner can employ his own inspecting engineer, if he desires an independent test, and all the large shipping companies, of course, do.

1847. What is done now? Say a shipowner is offered these tubes, and that he is offered them at a cheap price, and is inclined to put them into his vessel, but they are objected to by one of the surveyors to the Board of Trade, what is the appeal under those circumstances, except to a Court of Survey?—The Board of Trade, if they have reason to believe certain tubes are defective, can stop them—they can stop their certificate.

1848. Is it satisfactory that the surveyors of the Board of Trade should be obliged to act without any appeal to a scientific body capable of testing these tubes?—I think so.

1849. You think the practical test of the marine engineers sufficient?—Yes, I think so. A large number of the tubes, such as the bends, and special forms of that kind, I may say, are made by the marine engineers themselves, and are not bought from the tube makers.

1850. Do you mean to say that Messrs. Elmore and Company do not supply many copper tubes?—Yes; but they are straight tubes, as a rule.

1851. (*Mr. Roberts-Austen.*) A committee has recently been appointed to ascertain the cause of the failure of steel rails. Is that the kind of work which you think should be conducted in a National Physical Laboratory?—I do not think a National Physical Laboratory could carry it on by itself; it would have to be associated with engineers, or outside experience.

1852. But I may take it, may I not, that in all investigations where chemical or metallurgical questions bear upon engineering, then a National Physical Laboratory would be useful?—Yes; I take it that it would.

1853. The Alloys Research Committee to which you have referred—I may mention that I am a member of the Institution of Mechanical Engineers—is the one to which the institution has devoted the largest portion of these grants, is it not?—I think you and the Marine Engine Trial Committee are on about the same level, within a few pounds. I see by the table that £1,131 has been spent on the Marine Engine Trials, and £1,160 in the case of your committee.

1854. And those are larger amounts, as a rule, than any of the others?—Undoubtedly.

1855. Considerably larger?—Yes; we have had paid assistants in this case, you know, right through, and that has been an annual charge.

1856. Very important investigations required by engineers would be conducted in such a National Physical Laboratory?—Quite.

1857. The reason that the work of the Alloys Research Committee has been carried on is mainly due to the fact, is it not, that the Chemist of the Mint happens to be the Professor of Metallurgy at the Royal College of Science, and has facilities for directing work in State Laboratories?—I believe so.

1858. Had not such facilities existed, the necessity for some National Physical Laboratory would have been more apparent?—Yes; unless the Institution of Mechanical Engineers had had funds at their disposal to establish the means of carrying it out themselves.

1859. By precisely such a laboratory as we are contemplating?—Yes.

1860. Progress would have been more rapid, would it not, if certain constants which we have had to determine for ourselves had been available?—Quite so; that

comes under the head of what I said before, namely, that you never know when certain constants may be useful.

1861. The very important journal which you conduct, "Engineering," devotes a large portion of its space to the publication of the results of such investigations as are made, does it not?—Quite so.

1862. (*Mr. Siemens.*) Apparently you do not think it is of any great use to have an independent authority to whom people can appeal about measurements, or constants, or such like matters?—I said, in reply to a question put to me some time ago, that it would be a convenience.

1863. Just now, when Sir Courtenay Boyle asked you about it, you seemed to think that each man could test for himself the copper tubes, and all that sort of thing; would it not be a great convenience to have some authoritative place to appeal to in case of dispute?—In the case of steam pipes, I think not.

1864. I mean kindred questions. Of course what we have been speaking about is supposed to be a Physical Laboratory, and the mechanical questions which you mentioned—the form of riveted joints, the value of steam jackets, marine engine trials, and so on—are not purely physical questions?—Quite so.

1865. Those are mechanical questions, which would not fall to the Laboratory?—Quite so.

1866. Do you agree that it would be useful to have for physical questions an authority which would be accepted by everybody?—Yes, for physical questions, certainly.

1867. (*Dr. Thorpe.*) You have mentioned some researches which have been brought, I presume, to a successful completion through the instrumentality of the council of the Institution you represent?—Yes.

1868. Could you tell the Committee what number of other suggestions were brought to the knowledge of the council which were not acted upon?—I could not at once, but I could by making references. We have had at different times quite a large number.

1869. I venture to think it would be of interest to this Committee to know what are the questions which such a body as yours thinks require solving?—We have not had any brought before us quite lately, because all the funds that we have available for this class of work are fully occupied. Until we clear off some of these present researches we could not entertain any further ones. It is some years since we had the last series of suggestions made to us, and I do not quite carry in my mind what they were.

1870. Could you roughly tell us what proportion of the suggestions were not acted upon?—I should think we have now acted upon about half—roughly speaking.

1871. Perhaps you could undertake to put in exactly what were the suggestions that were brought before your council?—We have had a development of one or two of these researches brought before us: for instance, we had some experiments on friction at high velocities, and we have had the suggestion made that we ought to extend those experiments to friction at other velocities, and also that we should test more thoroughly than we have hitherto done the effects on different materials working at different velocities. New alloys for bearings are being continually brought out; hence it follows that no research of this kind is ever quite finished. There are materials available now which were not available when those experiments were made, and a lot of these things want bringing up to date.

1872. Could you kindly collect, for the use of the Committee the suggestions which have been made?—Yes; I think I could get the information by referring back to the council minutes. (*Vide* Appendix.)

1873. Is it the case that the particular subjects which were actually taken up were, to some extent, selected by the fact that they could be dealt with by practical men?—Not altogether. They were questions that were rather pressed upon the council as requiring *settlement*—particularly the Marine Engine Research Committee's work.

1874. But the particular type of investigation, perhaps both as a suggestion and as a practical matter, was, to some extent, dictated or controlled by the circumstance of the limitations under which the work could be done, was it not?—No; I think they arose solely from these subjects being the requirements of the members; they are subjects which members felt they wanted information upon.

1875. Is it at all possible that subjects would have been brought to their knowledge had the persons bringing them been aware that they were within practical conditions; that is, that they were feasible under the circumstances?—I think there has never been any hesitation in bringing subjects forward. There is one subject that has just occurred to me that is standing over now for an opportunity of being investigated, and that is the radiation from steam pipes, and the loss of heat by radiation from steam pipe flanges and from the exposed parts of engines, particularly as affected by the form of the object from which the radiation is taking place.

1876. Surely that is a type of investigation which is clearly within the province of such a Laboratory as is contemplated?—Yes, I think they could carry that out; it would not require any very large expenditure on apparatus, beyond, I mean, the apparatus they would naturally have.

1877. That is at present a subject which you have not been able to take up?—It it a subject which we have not been able to touch, but perhaps it is one that will be taken up at an early opportunity.

1878. It is one of importance?—It is one of very great importance now; particularly in view of the high steam pressures that are being used. The radiation question has become vastly more important in the last few years; when we were using steam at 60 lbs. or 70 lbs. pressure it was a matter of not very great importance, as the losses by radiation could be effectively controlled by the ordinary means available. With the high pressures now used the losses by radiation are far more important.

1879. I gather as your reason why you have not done a considerable number of these investigations—the other half that you speak of—is really that you have not had the funds to carry on the work?—That is so. We are building a new house for ourselves, which is costing a great deal of money, and we cannot do everything at once.

1880. (*Mr. Roberts-Austen.*) There will be no laboratory there, will there?—There will be no laboratory there.

1881. (*Sir Andrew Noble.*) I understood you to say, and I think you confirmed it just now, that about one-half of the important suggestions that have been made to your institution, you could not carry out?—We have not carried them out so far.

1882. Does that not show that if there were such a Laboratory as we are talking of they might have been referred to it?—Some of those might.

1883. Some of them could have been referred to it, and possibly most of them?—Quite so.

1884. (*Mr. Roberts-Austen.*) The results of the investigations conducted by the various committees appointed by your institution, have been of considerable industrial importance, have they not?—Yes.

1885. (*Sir John Wolfe Barry.*) Do you know of any exhaustive experiments on the influence of form in the design of such things as crank axles and the reciprocating parts of engines of late years?—There are no systematic experiments; it is a question of the survival of the fittest.

1886. Would you say there have been no comparative and systematic investigations?—There have been a great many comparative investigations, but not systematic ones. In the earlier days, when locomotive superintendents used not to design their own engines, but used to buy them from various makers, there was a very great variety in the forms of axles, and certain of these forms were found to give better results than other forms, and they were gradually adopted. It is a question of the survival of the fittest.

1887. But it is a matter of great importance, is it not?—Yes, it is.

1888. The form of junction between the upright part of the crank and the horizontal part of the crank is a matter of the highest importance, is it not?—Yes, within certain limits. But there are a certain number of proportions which appear to give fairly equal results; if you take the practice of the leading companies you will find there are important differences.

1889. I am only using that as an illustration of a general statement?—Quite so; I understand.

Dr. EUGENE F. A. OBACH, F.I.C., called; and Examined.

Dr. Eugene F. A. Obach, F.I.C.

1890. (*Mr. Rücker.*) I think you are a member of a number of scientific and technical societies?—Yes, I am.

1891. You were educated at the Polytechnic High School, Stuttgart, and the University of Leipsic?—Yes.

1892. You have also worked in various important chemical laboratories, among others, that of Fehling, Victor Meyer and Kolbe?—Yes.

1893. And in the physical laboratories of Zech and Wiedemann?—I have.

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1894. You have also had, I think, considerable experience in the practical application of scientific principles to industry?—Yes, for 22 years.

1895. You are Chief of the Physico-Technical Laboratory of the firm of Messrs. Siemens?—Yes, I am.

1896. Have you given any special attention to the question of the establishment of a National Physical Laboratory?—Yes, I have considered it.

1897. Do you think—to take the things in order—that for the systematic determination of physical constants and numerical data useful for scientific and industrial purposes, there is work to be done by such an institution?—Yes, I think such an institution would be desirable.

1898. Could you give me some instances of the constants which you think it would be desirable that the Institution should determine?—You might take almost any physical constants—the specific gravities of different saline solutions at various temperatures, the vapour tensions, viscosities, electrical conductivities, optical properties, etc. Our knowledge is very incomplete in this respect. You hardly ever find what you require in the published tables. The temperatures for which the constants are given rarely reach high enough. They may go up to thirty degrees, and you want to know them at sixty or seventy. I may claim to have had some experience in utilising such data, and I have frequently had to determine them myself as well as I could, as they could not be deduced from the tables. I may, perhaps, be allowed to illustrate this by an example. A short time ago, I had to design a voltameter for technical purposes, in fact, for the production of large quantities of pure hydrogen. The use of platinum electrodes and acids in the usual way was out of the question, on account of the great initial cost, and I had to resort to iron electrodes in an alkaline solution. Ought we to take potassium or sodium hydrate? This was the first question to decide. Certain data could be found, but they were incomplete, and did not enable me to decide one way or the other, particularly at higher temperatures; for instance, the data for sodium hydrate solutions of different concentrations were not given for temperatures above the ordinary, and we had to determine them ourselves. The various concentrations had to be tried, as it appeared quite possible that a solution, which had a higher specific resistance at the ordinary temperature than another of a different concentration, might yet be more advantageous at higher temperatures, as the curves representing the dependency of resistance on temperature for various concentrations frequently intersect each other. Similarly, for potassium hydrate solutions, the data were also too incomplete for our purpose, and we had to test these as well. Then, other things came into consideration, such as the vapour tension, which increases rapidly with rising temperature, and in consequence of which large quantities of vapour escape with the gases, so that the voltameter consumes, as it were, considerably more water than it should do, and the aqueous vapours must be condensed. Another important point was the viscosity of the solution. I employed a wire-gauze diaphragm between the iron electrodes, and if the evolution of the gases was too rapid in the viscous solution, they were forced through the meshes of the gauze; it was, therefore, desirable to have a very thin solution, so as to allow the gases to escape as quickly as possible. A twenty per cent. sodic hydrate solution, which has about the maximum conductivity at ordinary temperatures, is very viscous, the question arose, how much thinner it became at higher temperatures? I could find no information on that point in the books at my disposal, and we had to determine the viscosity of that solution at different temperatures ourselves. We did it only in a rough-and-ready sort of way, as this was sufficient for the particular purpose. I simply took a pipette, surrounded by water of the desired temperature, and measured the time the solution took to run out. The solution was found to be less viscous above seventy-five degrees Centigrade than water at the ordinary temperature. Taking everything into consideration, a temperature of about sixty degrees Centigrade was finally decided upon as the most suitable. In this particular case, therefore, we required to know the electric conductivity, the vapour tension and viscosity of two different solutions of different concentrations, and at different temperatures, and all these data I ought to have found in a book of reference within half-an-hour, not only for the chemically pure materials, but also, I think, for the commercial ones.

1899. That is a capital example?—In coming up others occurred to me: of course, I have very likely forgotten some of the points which came in.

1900. I should like to put it to you generally, do you think that there are many such physical constants which would be useful in a large number of cases which still want determining?—I certainly and most decidedly think so.

1901. Then the question arises whether or no it would be possible to select from among the large number of investigations that have been suggested what problems ought to be first dealt with in selecting them?—Yes, that is so.

1901*. Do you think a body of the sort we have been speaking about would have any difficulty in making the selection?—I should think not. Of course, it is a very vast field, and the chief difficulty would be in making this selection.

1902. Looking at it as a practical man, do you think that if the Government were to see fit to endow such an Institution as this, a very grave difficulty would arise on account of the vastness of the field; or do you think that a number of sensible men would be able to select what problems were most important?—I believe a selection could be made of the most useful subjects upon which data are required first.

1903. In the next place, do you think that a Physical Laboratory by itself would be useful, or would it require to be supplemented by a Chemical Laboratory?—In my opinion it would be impossible without the aid of a Chemical Laboratory.

1904. By that you mean, I suppose, that if it were a Physical Laboratory in the first instance a certain amount of chemical work would necessarily be required?—Yes, absolutely.

1905. On the other hand, it would be possible to regard it as a primarily physical institution?—Yes; a Chemical Laboratory would only have to supply the materials for the constants to the physicists.

1906. It would have to look after the purity of the substances employed?—Yes, and the methods of testing for purity. It would be chiefly to see that the physicist cannot go wrong with his materials.

1907. But there would be no difficulty, you think, in regarding the Chemical Department as subsidiary to the Physical Department?—No, I do not think there would.

1908. In the next place, have you any views as to the kind of original work that should be carried out in a National Physical Laboratory?—I should say that it ought to consist chiefly in the systematic determination of constants, for instance, the vapour tensions and conductivities of various salt solutions at different temperatures, and that kind of thing.

1909. I did not mean so much that you should give us special instances, but do you think that the work of such an Institution would necessarily compete harmfully with the private observer?—I think not; I think it would rather relieve the private observer of this class of work, which I should say is an advantage to science.

1910. Do you think there are investigations of a kind which the private observer is not likely to take up?—Yes, there are.

1911. But which could be carried out here?—Yes. If I may be allowed to say so, I consider the chief value of the work would consist in the materials of which the various constants are determined being identically the same and in the constants being all ascertained by uniform methods, so that even if the absolute values should not be quite correct they would be at least comparable. There is such a great difficulty on that point now. You get one result from one source, another from another, and if you want to join them to get an intermediate value you find they do not fit. In this Physical Laboratory you would have, as it were, a connected series, and that would be most useful; it is frequently not so much the absolute values which are required as the comparative ones.

1912. In like manner, do you think there would necessarily be any re-duplication of the work of an Institution of this sort, and that, say, of the Reichsanstalt, in Berlin, or the Bureau International in Paris, or do you think these Institutions might work in harmony one with the other?—My opinion is that the work should if possible be divided, so that no labour is wasted; say, let it perhaps be more the optical work in one institution, and more the electrical work in another institution, and so on, in order to accelerate matters. The chief consideration is that we should get these results as soon as possible, and thus save time and expense.

1913. In other cases, where two independent results are desirable, arrangements could be made for carrying on investigations simultaneously?—Yes, that would be very desirable, indeed.

1914. Have you found any practical difficulty in your own work with regard to the testing and verification of instruments?—No, of course you must have your instruments standardised. There is no difficulty in getting thermometers standardised.

1915. That is not quite consonant with the evidence we have received with regard to thermometers; are you aware that at Kew there is no hydrogen thermometer?—Yes, but I know they have a platinum thermometer.

1916. Which is not yet standardised?—I did not consider it from that point. The present Institution may be incomplete, and it would then be desirable to bring it up to date, so as to have the purely physical work separate from the standardising work. It should be in connection with the Institution we are speaking of, and there ought to be some sort of supervision or advice—I do not know exactly how to put it.

1917. Then you would be generally in favour of the view that for such standardising work as is already carried out at Kew an extension of Kew would be the wisest plan?—Exactly, that is what I think should be done.

1918. Do you think, as a practical man, that the practical world would be satisfied if the main government were in the hands of the Royal Society, provided always that technology was fully represented on the governing body of the Observatory? Perhaps you have not given any attention to that question?—I have not considered that specially.

1919. It has been suggested that the Government might wish to deal with one body, and that, therefore, if any funds were given, the Royal Society might be the body to whom the direct administration of those funds would be entrusted; we are anxious to know whether this would commend itself to technical men if it were clearly understood that the governing body of the National Laboratory would consist not only necessarily of Fellows of the Royal Society, but also of men eminent in practical work?—I should think it would; I think that is all that can be expected.

1920. That would satisfy you?—Yes, if technology is adequately represented.

1921. Then in the next place, with regard to the construction and preservation of standards of measurement, do you think that the proposed Institution could be useful in that respect?—I think so.

1922. Do you think, with regard to these matters, that there should be any connection between the proposed Institution and the existing standardising offices of the Government—both the Standards Office and the Electrical Standards Office?—I think so, certainly. I consider a standard is a standard whether it is an electrical standard or a standard of weight, or whatever it is, and that the standards ought to be connected together in some way. I do not see why an electrical standard should be treated differently from a standard of weight.

1923. You would have the new Institution in some way associated with the existing Board of Trade Institutions?—Yes, in my opinion it should be connected with them.

1924. (*Sir Andrew Noble.*) You said that there was a very large field, and an enormous field, that the Physical Laboratory might have to work in?—Yes.

1925. But, of course, everything cannot be done at once, and I suppose you would agree that the work which is most applicable to the industry of the country would probably be that which the governing body would select first for the Physical Laboratory, leaving other researches to private observers?—Yes. Of course, a decision would have to be made in that respect as to what ought to be done first.

1926. What I mean is that it is most likely that the Government would be inclined to give money to what would benefit the trade of the country?—No doubt.

1927. Under that view what would probably be selected first for the Physical Laboratory to work upon would be the determination of such constants, for instance, as would be useful for the industry of the country?—Yes, that would be so.

1928. I suppose the physical constants which it would be important to the electrical industry to determine, would be, among others, the electrical resistance of metals and alloys, especially under various conditions of temperature?—That would be part of the work, certainly; but I expect there would be some difficulty in obtaining generally useful results, on account of the variability of the commercial metals.

1929. It would also, I suppose, be important to determine the effect of heat upon various insulating substances?—Yes, that would be very useful.

1930. Then, as regards instruments, I suppose you would agree with reference to what Professor Rücker has said about the higher classes of thermometers, that is, thermometers going up to high temperatures, such as the hydrogen thermometer, and also pyrometers of various sorts, that it would be desirable that the public should be able to have these—no doubt by paying a fee—standardised at a Physical Laboratory?—Yes.

1931. I think platinum thermometers capable of determining the rise of temperature in electrical apparatus have been very much used in dynamos?—Yes, the platinum thermometer is being more and more used in dynamo testing, and in the Laboratory also.

1932. That also would be a very suitable instrument to have standardised?—Yes, very; I think it is necessary to have it.

1933. (*Dr. Thorpe.*) To have it, or to have it standardised?—To have it, and then to have it standardised also.

1934. (*Sir Andrew Noble.*) In a great number of pyrometers, even the Siemens pyrometer, after use we have found, when comparing them in one place and another, a great variation; should you not be able to have these sent up from time to time and compared with standards?—Yes. That is usually done now by having them compared with the standards at the works from where they come.

1935. Yes, I know, but it would be more convenient, would it not, to have it done elsewhere, especially if you are supplying them to other people, who want to know if they can be relied upon?—Yes, it would perhaps be desirable to have them independently tested.

1936. There should be an independent inspection of them?—Yes.

1937. To the trade generally such a Physical Laboratory, I suppose, would be of immense value?—I think it would be of very great value indeed to the trade generally.

1938. (*Mr. Roberts-Austen.*) You have been speaking about pyrometry; in addition to the electrical resistance pyrometer, great use is now made of thermo-junctions, is it not?—Yes.

1939. But comparatively little is known as to the best metals to be used for such junctions?—That is so.

1940. It would be very desirable, would it not, that investigations should be conducted, having in view the determination of that question?—I think that would be very desirable. A platinum resistance thermometer cannot be employed always, and you have sometimes to employ a small instrument for measuring temperatures in a limited space, where a resistance thermometer could not replace the thermo-junction. I have very largely used the thermo-junction in addition to the resistance thermometer.

1941. And as yet very little is known, for instance, whether it is preferable to use platinum in association with platinum iridium or platinum rhodium?—Yes.

1942. There is still room for very important research in that direction, is there not?—I think there is, as the thermo-couple has not been taken up much as a thermometric instrument as yet; it has not been standardised anything like the platinum resistance thermometer has, so far as I know.

1943. But it is exceedingly desirable that that should be done?—Yes, I think it is very desirable.

1944. Then again, with regard to the great electrical industries of the country, the question of the alloys used for resistance purposes is of vast importance to them, is it not?—Yes, of course, there is a large field for investigation there, because it is not only a question of the resistance at the time or shortly after the manufacture, but it is also a question of the behaviour towards currents and higher temperatures, and so on. There is a great deal to be done in order to find out what are the more permanent alloys for the purpose.

1945. The failure of resistance coils, especially in the tropics, has recently given rise to great anxiety, has it not?—I am not aware of that.

1946. The alloy known as manganin is a very important one, and one of great industrial importance, is it not?—Yes; but as regards manganin, my opinion is that it is not so suitable for high-class standards; for works standards, for technical resistances, yes, it is of great importance, but not for actual authoritative standards.

1947. As a matter of fact it is an alloy which was found out in the great Berlin Institution, as the result of an investigation?—Yes.

1948. Therefore that important alloy is the product of just such a laboratory as we are contemplating?—Exactly, and so are other alloys, too—the nickel copper, for instance, which I believe is more suitable for standards than manganin.

1949. (*Dr. Thorpe.*) I should like to ask you a little about the statement you have made as to the desirability of supplementing the installation which you are contemplating by a well-equipped chemical laboratory. Perhaps you would kindly tell the Committee what class of chemical investigation you think it is desirable that the laboratory should undertake?—I think the work which the chemical laboratory should undertake should be only in connection with, and supplementary to, the physical work, and that it should not do independent chemical work. It would be, for instance, for the production of pure substances for physical constants; it would have to do with methods of producing pure materials—or rather of purifying them—and also with methods of testing for purity, so that when a large amount of labour is being bestowed on

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the determination of the physical properties of a certain substance one can be quite sure one has an absolutely pure substance in hand, and that the labour has not been wasted. When one subsequently finds out that the substance which has been used has a certain percentage of impurity which affects its properties—its vapour tension, or its conductivity—then the whole labour is lost. I think if such an auxiliary chemical institution were in existence it would give confidence in the results of the Physical Laboratory, both in the eyes of technologists, and in fact of everybody else using the results. I think it would be much more satisfactory that, speaking as a member of the Physical Laboratory, one could say: "By our own tests we have found this to be a pure substance"—not simply that "we have bought it as pure from so and so," which would hardly be satisfactory, coming from a Government institution. You must vouch for it, as it were, that the substance is pure. I think, considering the great labour to be bestowed upon this work it should be as nearly final as possible, so that one shall not find afterwards that the work is not quite up to the mark, and has to be repeated. This question of getting pure substances is of the utmost importance, and I think a very difficult problem, at least in a good many cases.

1950. Your idea is that the chemical department should be strictly supplementary to the other?—Yes, that is so.

1951. That it should not be in any sense a partially independent organisation?—That is my view at present. I have only considered it from the Physical Laboratory's point of view, and I did not put the question to myself whether it would be desirable also to have a National Chemical Laboratory.

1952. But I presume there are other researches of a more independent character connected with chemistry that are within your mind at the present time which such a laboratory could undertake?—I daresay there are a good many, but I did not think that out. I know that at the Reichsanstalt they do a lot in the chemical laboratory which is not strictly required for physical work.

1953. Speaking as a practical man, do you know of anything which industry would require them to undertake. Are you prepared at once to say that you know of such things?—I could not mention any just now, besides the methods of testing, and of purification of substances. I was considering the physical constants, which, of course, are of the greatest importance to the chemist also, and I cannot at the moment think of any independent work which might be suitable for the Chemical Laboratory.

Friday, 25th February, 1898.

PRESENT:

Mr. A. W. RÜCKER, D.SC., F.R.S. (in the Chair).

Sir ANDREW NOBLE, K.C.B., F.R.S.
Sir JOHN WOLFE BARRY, K.C.B., F.R.S.
Mr. W. C. ROBERTS-AUSTEN, C.B., F.R.S.
Mr. ROBERT CHALMERS.
Mr. ALEXANDER SIEMENS.
Dr. T. E. THORPE, F.R.S.

Mr. L. BLAIKIE, *Secretary*.

Lieut.-Gen. Sir R. Strachey, G.C.S.I., F.R.S.

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Lieut.-General Sir RICHARD STRACHEY, G.C.S.I., F.R.S., called; and Examined.

1954. (*Mr. Rücker.*) You are chairman of the Meteorological Council, and for many years you have been a member of the Kew Committee?—Yes; I had been a member of the original Meteorological Committee, and joined the Meteorological Council when it was formed, and I have been on it ever since. I became chairman of the Council in 1883, and the whole of that time I have also been on the Kew Committee.

1955. And in that capacity you have taken a great deal of interest in the standardising of instruments?—Yes. Of course, for the purpose of the Meteorological Council we have to see that all the instruments are properly verified or standardised, and practically the work has been done for us entirely at Kew.

1956. Have you paid any special attention to the question of the establishment of a National Physical Laboratory?—So far as I have heard the question discussed I am perfectly satisfied that it is a very proper thing to establish—there can, in my opinion, be no question about it.

1957. You know by the terms of the reference to this Committee we are here to report upon the desirability of establishing a National Physical Laboratory for the testing and verification of instruments for physical investigation. Do you think that more should be done than is done at present at Kew?—Certainly. What is being done at Kew is on a comparatively small scale, and although as far as it goes it is satisfactory, it necessarily is not so efficient as a national establishment having that object in view should be.

1958. As a member of the Kew Committee, do you find that the work done there is hampered owing to the want of a larger establishment?—Certainly; there is no doubt of it.

1959. Taking next the systematic determination of physical constants and numerical data useful for scientific and industrial purposes, do you think there that some better organisation in the way of organised method for investigating those things is necessary?—There can be no question about it. There is at present no establishment, either private or public, in the British Islands, which undertakes duties of that sort, and certainly it is highly important that there should be such an establishment.

1960. The third question in our reference is whether the work of such an institution, if established, could be associated with any testing or standardising work already performed wholly or partly at the public cost. Have you considered that question at all?—I think that the existing establishment at Kew might very advantageously serve as a nucleus for such an institution, and anything that is done in this direction would, I think, be better carried out by way of natural growth and expansion than by attempting to create at once what one might eventually hope to find come into existence.

1961. Regarding Kew as being supported partly out of public cost, insomuch as it is a public building, you think that the extension of Kew would be an important means of carrying it out?—Certainly; as far as I am able to judge. Everyone knows the difficulty that exists in England in the way of getting public money for carrying out objects of this description, and therefore it would be prudent to begin in a modest way.

1962. With regard to the government of such a laboratory, if established, have you formed any opinion as to that?—I think that there are obvious advantages in placing the general control of such an institution, if it is established, under the general supervision of the Royal Society. For some years past, and as far as my information goes, there is an increasing tendency for the Government to entrust the Royal Society with what I may call its scientific conscience. The Royal Society advises the Government on all such matters, and I think that some organisation in connection with the Royal Society would probably be more satisfactory than any other arrangement.

1963. (*Sir J. Wolfe Barry.*) I wish to ask you whether, from your knowledge of Kew, you think the site is suitable for a further development?—I think there are advantages and conveniences in having an establishment of that sort near London, but not actually in it, and although the ground that is now occupied at Kew is relatively small, I do not see that there should be any difficulty in getting a larger portion of the Old Deer Park for any extension that would be necessary. The Board of Works have made no difficulty in permitting the expansion, such as it has been, of the Observatory at Kew; they have allowed us to add to the old building, and they have also enabled us to take a small plot of ground there, and I should think there would be no difficulty in obtaining a larger space.

1964. Assuming sufficient area of ground could be got adjoining the Observatory, you think it would be a very suitable place?—I think so.

1965. One other question with regard to the government of the laboratory. I think it may very likely be found that the commercial interests of this country would

be largely bound up in the well-being of a physical laboratory, and in saying that the Royal Society would probably be the immediate governors, I suppose you would anticipate that commercial interests would be represented as well as strictly scientific interests?—Certainly.

1966. You think it would not be necessarily confined to members of the Royal Society?—Not at all.

1967. (*Mr. Rücker.*) Have you any other point to put before the Committee?—There is one matter that has attracted my attention in connection with the work of the Meteorological Council, and to some extent the same remark applies to the establishment under the Kew Committee, which should, I think, be considered in forming an establishment with officers and clerks, such as the present proposal would involve. I look upon it that it would be quite necessary for a satisfactory result to be obtained that some arrangement should be made for giving the staff pensions, or superannuation in some form. I speak after having had long experience both in this country and in India as to the management of a staff of clerks, and am satisfied that the only way really of keeping them contented is that they should look forward to a gradual and reasonable increase of salary. Now, the only way in which that can be done is by removing the older men from the top, and allowing the younger men to come up, which on other grounds is also desirable. Unless you have some means of giving pensions, or something equivalent to them, stagnation takes places and gives a great deal of trouble to the managing body, constant complaints arise, and it disheartens the whole of the staff. Also, as we all must know, there is a further advantage in infusing new blood from time to time into an establishment of this sort.

1968. (*Sir John Wolfe Barry.*) Assuming, however, that this were a Government physical laboratory, would not the employees come under the ordinary regulations as to retirement as in the Civil Service. I do not know. I am speaking in ignorance?—Not necessarily, even though the institution was maintained by public funds.

1969. (*Mr. Rücker.*) It is not so at Kew?—The Observatory at Kew is a private establishment, not aided by the Government. It is not so with the Meteorological Office—the staff is not pensioned.

1970. (*Sir John Wolfe Barry.*) I was treating this on the assumption that it was a Government physical laboratory?—So far the Meteorological Office is maintained by a Parliamentary grant.

1971. Who appoints the employees?—The Meteorological Council.

1972. They are not appointed by the Civil Service Commissioners in any way?—No; the Treasury at the outset let it be understood that they would have no responsibility whatever in connection with it.

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1973. Merely for the sake of assumption, if it were a Government establishment, and the employees were appointed as they are to other posts, would the Civil Service rules meet what you have been saying?—No doubt they would. In a somewhat analogous office, for instance, the Observatory at Greenwich, they are pensioned. When I say that I should add that, though a certain number of the subordinates are not pensioned, the permanent staff are pensioned.

1974. And they come under the rules as to retirement?—Yes.

1975. And you consider that would be satisfactory?—I think it would be quite satisfactory.

1976. You think that they would be satisfactory in themselves?—I think so. But other plans might be suggested for doing the same thing. You might have an arrangement such as we have on the Indian railways, namely, a provident fund, to which the clerks would make a contribution themselves, while the Office would also make a contribution, and these amounts would be put by and would be allowed to accumulate at interest, and the subscribers would receive the accumulated amount when they retired.

1977. (*Mr. Rücker.*) Considering on what a relatively small scale it would be, and that there would be a comparatively small number of employees as compared with a great railway, do you think that the fact that such a system was introduced on the Indian railways is sufficient to show that it should be adopted here?—Such a scheme as I have talked of is rather more complicated and troublesome than a simple pension, but there is no difficulty about it. Nothing depends upon the number of subscribers to what you may call the provident scheme; the individual servant's contributions are put by, and they accumulate exclusively for his advantage—there is no difficulty about it. What has induced the authorities in India to adopt this system is that there is always doubt as to the financial result of a system of pensions—you cannot tell how long people will live, and how many there will be who eventually become entitled to a pension, but under the provident fund arrangement all such difficulties are avoided, everybody takes back what he has subscribed, with the sums contributed from time to time by his employers. This is so arranged as to give an amount considered suitable for superannuation, and may be regarded as deferred pay, which in fact a pension also is, though given in a different form.

Professor W. E. Ayrton, F.R.S., called; and Examined.

Professor W. E. Ayrton, F.R.S.

1978. (*Mr. Rücker.*) You are Dean and Professor of Applied Physics at the City and Guilds of London Central Technical College?—Yes.

1979. And you are Past-President both of the Institution of Electrical Engineers and of the Physical Society?—Yes.

1980. You were a member of the Board of Trade Committee on Standards for the measurement of electricity?—Yes.

1981. And you have also been cognisant from the first of the various subjects relating to the establishment of a National Physical Laboratory, and you have paid a great deal of attention to the matter?—Yes.

1982. The reference, with which I think you are acquainted, states that we are to consider and report upon the desirability of establishing a National Physical Laboratory for the testing and verification of instruments for physical investigation. Do you think that is desirable, and would you mention as an example any instrument which you think could be tested at such an institution?—I think it is most desirable and most necessary, because there are many instruments, several of which are in quite common use, for which there should be public facilities for having tested at an institution where it should be possible to obtain a public impartial certificate of their accuracy or inaccuracy. I would instance pressure gauges of various kinds used in connection with boilers, compressed gas, and so on. I have in my own laboratory and engine rooms a number of pressure gauges, some of them reading up to 180 atmospheres. Now, I am not aware of any place to which I can send any one of these gauges and ascertain whether it is correct, and clearly to test a gauge reading to 180 atmospheres by means of a column of mercury would be very cumbersome. It would require a column of mercury 450ft. high; and, therefore, it would be most important that there should be established some laboratory, some body to which such a gauge could be sent to ascertain what degree of accuracy it possessed.

1983. May I interrupt you for a moment. We have had in evidence that such gauges are tested by the makers; do you think that that alone is a satisfactory test?—No; I do not. I want to know whether the makers have calibrated the gauges correctly. Of course, they say they have, but I want to know whether they have or not.

1984. You think that some independent institution is needed for that purpose?—Certainly.

1985. With regard to the speed indicators, what have you to say?—A speed indicator is an apparatus very much used now. Of course, a simple speed counter could be easily tested; it is a mere question of the number of teeth on the wheels which gear together. But a speed indicator, an instrument to indicate the speed at any moment, cannot be made in that way. It may be something like a Watt's steam engine governor. Some are constructed in that way, but however they are made, they are very often, I find, wrong, and, therefore, that is another example where it would be desirable that it should be possible to send such an instrument to an independent body who would give an impartial certificate.

1986. Have you any other examples you can give us?—There are certain optical instruments, one of which I have got on my nose at the present moment (*the witness here touched his pince-nez*), that I think it would be most desirable to have tested. At the present time people go to an ophthalmic surgeon, who examines the eyes and writes out the formula for a pair of eye-glasses, and that is taken to an optician. Whether the optician does his work properly or not the public are absolutely unable to judge. In the case of astigmatism each glass should be

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inserted in the frame in a different way, the eyes may differ and the two glasses must not be interchanged. Glasses, as you know, differ enormously in value, and it is desirable that the public should have some means of ascertaining whether they have got their money's worth. At the present moment, indeed I may say generally, I have with me two pairs of glasses. This pair is worth a guinea, and this other pair ninepence. Now, a pair came under my notice a little time ago purchased by a lady (from one of the best opticians in London, having the highest reputation), for which she paid a guinea, and she showed them to me as being very good quartz eye-glasses. I looked at them, and I said at once: "They are not quartz; they are glass; they are only worth a few pence." She was very much astonished, and I took the glasses myself to the optician, and I said: "I know you sold these for quartz, and my friend paid a guinea for them, but if you look at them you will find that they are glass." "Of course they are; I suppose they got into a wrong drawer," was the reply. But if I had not seen them, or someone else who knew the difference between glass and quartz, she would have paid a guinea for a thing which was not worth more than sixpence or ninepence. Therefore, it seems that with reference to spectacles and eye-glasses, instruments in very common use, that it would be very desirable to have an independent body for testing them to ascertain and ensure that the surgeon's formula had been rigorously carried out.

1987. You would have it possible to send them to such an institution just as telescopes are sent to Kew?—I would have it possible to send them. It is a moot question how far the laboratory should undertake to write out the formula originally; in other words, whether it should not also include the testing of the eye. I mean in the cases where there is no disease, it would be extremely convenient if one could go to a laboratory, and without paying a very large fee, have one's eyes examined, and be told not only whether the glasses fulfilled their purpose, supposing one had got the glasses, but to have the written formula supplied as well.

1988. That would be rather an anthropometric than a physical laboratory?—I do not know. Of course the eye is the optical instrument. If it is diseased the person should go to a surgeon. Take the case of eyes without disease, but at the same time which require artificial aid. I do not know whether it would be desirable, but certainly it would be extremely convenient to have this. But whether the laboratory is to test the eyes or not, there is no question that it would be desirable to have a place where the glasses themselves could be tested.

1989. With regard to the standards of light, do you think that is a matter that the laboratory could take up with advantage?—I think so. There is a very considerable vagueness with reference to the standards of light. As to the accuracy of the standard, of course there are a great number of different kinds of standards; some gas standards, some not, the amyl acetate standard, for example—and it is important to notice that very few people are aware what is the exact relationship between the amyl acetate standard and the English candle. The amyl acetate standards which I have myself tested, and which have been sent over from Germany, have differed very much in their illuminating power as compared with the same standard used in all cases. Very possibly they were intended to differ, but standards of light, as a rule, have nothing stamped upon them to indicate what light they are supposed to give, and when you test them there seems to be considerable vagueness. I believe a committee has taken this up, of which you yourself are an important member, if not chairman, but I think they have only dealt in their recommendations with the 10-candle standard. For an arc light you want more; you want a 50 or 100 candle standard. I have in my laboratory a standard—one of the latest, of the Dibdin 50-candle standards. Now, the variation of that is 4 or 5 per cent. without any apparent cause: it may be the quality of the gas, or something of that kind. But using it as specified by the maker, and testing it by comparison with such a standard as the Harcourt pentane standard, it is quite certain that the Dibdin 50-candle standard varies 4 or 5 per cent.

1990. And as those standards are for large quantities of light, that would lie outside the work of referees?—I imagine so from the report of that committee.

1991. Is there a satisfactory standard of electrical capacity?—No; there is not. The Board of Trade electrical laboratory does not undertake the testing of the capacity of condensers at all, whereas of course the capacity is a very important element in the construction of a submarine cable. The speed of working depends upon the capacity; it is also an important element where power is supplied by alternating currents. I came across only the other day a statement with reference to the latest Atlantic cable of 1894. "The mean capacity of the whole cable when tested in core lengths at 75 degrees was 0.4207 microfarads per knot." It is given to four significant figures, and yet I have every reason for imagining that their standard may have been a half or perhaps even three-quarters per cent. wrong. I do not mean any particular standard, because the only standard condensers which we have are made practically, almost entirely I might say, at any rate certainly in large numbers by Dr. Muirhead, and I enquired a few years ago from him what sort of accuracy he would guarantee with his standards of capacity, which of course would be used in making those tests of submarine cables, and he wrote to me:—"As it is difficult to compare capacities within one-fifth per cent., I should allow, say, one-half per cent. variation from the nominal value" in a condenser that he passed. So that the people who were testing this last Atlantic cable of 1894, and who give their answer, 0.4207 microfarads to four significant figures, were very likely using one of their condensers which was very likely a-half per cent. wrong; that is to say, the third of the four figures may have been wrong by 7 or 8 parts; and, therefore, the fourth figure was quite meaningless. Of course, it is quite a misleading idea of accuracy. People probably do not realise that the so-called standard condensers, of one-third of a microfarad, for example, made by the instrument-maker may have large errors even in the third significant figure. Therefore, it would be highly desirable that a standard condenser should be constructed by such a National Physical Laboratory, or, better still, a series of such standards, and that there should be facilities for comparing those real standards with any condenser which an electrical engineer or instrument maker might desire to send for testing.

1992. With regard to standards of self and mutual induction, what have you to say?—The same thing applies, but to a less extent. That is, instruments professing to be graduated in the unit—or in multiples of the unit—the Henry, are now sold commercially, but there is nowhere in this country to which you can send such an instrument and ascertain officially whether it is one per cent. or ten per cent. wrong.

1993. Have you considered what the Board of Trade Laboratory could do in such matters?—I am not quite clear about the Board of Trade Laboratory as to whether it is intended to test types of instruments only.

1994. I may answer that question for the Board of Trade; they have lately undertaken to certify individual instruments.—Any number?

1995. I believe any number?—Because I know there is a vagueness and a doubt in the minds of those who might send instruments to the Board of Trade as to whether they can only send a new pattern instrument, a new pattern supply meter for instance, and get it certified as a proper type of meter, or whether they could take a hundred all of the same kind and get them tested—there is a vagueness about that. I do not know. But in any case the Board of Trade Laboratory, as at present constituted, is not supposed to construct new standards, for instance, the standard of capacity, the standard of mutual induction. Nor is it supposed to carry out investigations in order to ascertain whether the ampere, or the ohm, or the volt, which were mentioned in the Order in Council, are correct, or whether they are incorrect, or by how much they may be incorrect; that does not fall within the province of the Board of Trade Laboratory. Now, it is most important that not merely should we be sure that the standards at the Board of Trade Laboratory are not altering, but, as they were based on the theoretical units, it is important that we should ascertain what is the difference between their standards and the ideal standards, and that we should make the concrete standards at Richmond Terrace approach the ideal standards closer and closer as time goes on. Such investigations might form a very important part, I think, of the work in this particular that might be done by a National Physical Laboratory. At present such work is done wholly privately in this country, wholly outside the Board of Trade. It may be within the knowledge of some of us that there was a determination of the ohm made last year; the determination of the ampere is being made now, and a fresh determination of the ohm will be made with a new and entirely fresh apparatus, for which money has been provided privately—£700. Now, all that is certainly the duty of some public body, and, indeed, is being performed in Germany by a public body, the Electrical Department of the Reichsanstalt.

1996. Are there any other electrical properties and objects that could be tested at such an institution; take

insulation and conductivity, for instance?—It would be certainly desirable that specimens of conductors of copper or other conductors should be able to be sent somewhere and their conductivity certified to. At the present moment there is a very great vagueness about copper. Thirty years ago or more Dr. Matthiessen made experiments on the electrical behaviour of copper, as well as of other substances, and he told us what we might expect if our copper was chemically pure, he attained a sort of ideal standard, a sort of haven to which we might hope to approach as time went on, but which commercially could hardly ever be reached. Commercially, however, we have got even far beyond that, and instead of now saying that the copper is to have, as we did a few years ago, 95, 96, or 97 per cent. of the conductivity of pure copper, we now say it is to have 101 or 102 per cent. of the conductivity of pure copper. Well, it would be desirable, of course, if we could send specimens, and could learn whether they had such conductivities, and it would be also extremely important to know why is it that copper can be prepared in tons to-day having a higher conductivity, and, therefore, electrically better than Matthiessen could prepare it in a small quantity in a chemical laboratory. For some time it was thought that the copper was harder and more condensed and closer grained, and, therefore, had better conductivity, but experiments made in my laboratory do not seem to bear that out. I have found specimens of copper, which have been submitted to me to test, having relatively a low specific gravity, and with a very high conductivity, much higher, I mean, one or two per cent. higher than the chemically pure copper dealt with by Matthiessen. So partly to ascertain whether samples submitted to us are of a certain quality, and partly to ascertain what is the real limit up to which we can go—is it 103 or 104 per cent.—partly for the one purpose, and partly for the other, a National Physical Laboratory would be extremely valuable.

1997. That is a matter of practical importance, you think?—It is of very great commercial importance in connection with electrical transmission of power, and electric lighting.

1998. Can you tell us whether there is any institution where the change of resistance of a coil with change of temperature could be certified?—No. If you send coils to the Board of Trade, the custom has been to give the resistance at the particular temperature, namely, the temperature which the coil had on the particular day, in fact, the atmospheric temperature; but when you are going to use that coil it will have other temperatures, higher or lower: that is, the atmospheric temperature will change. Now it is very difficult when you have got coils made of substances like platinum-silver, or manganin—it is very difficult to measure the temperature variation. It is small in the case of platinum-silver, but at the same time it is important if the change of temperature is considerable. Therefore, in my case, and in the case of others who, like myself, are dealing with electrical research, it would be of the utmost use if I could send coils to such an institution as we are speaking of, and ask them to give me the resistance at every degree, from 15 degrees to 25 degrees C., for example. I am trying to do that myself at the present moment, there being no institution where I can get it publicly done.

1999. Do you think that this is work that the Board of Trade Laboratory might reasonably do, or is it work that might reasonably be done at the National Physical Laboratory instead?—Well, it is work occupying a considerable time—I am not clear that the Board of Trade, with anything like the staff they have got, could undertake such delicate work. It is delicate, troublesome, and laborious, and, unless the results are obtained with considerable accuracy, they are quite valueless.

2000. Can you say whether if it is done under the name of the Board of Trade Laboratory, or under the name of the National Physical Laboratory, a considerable extension of means will be required?—Yes.

2001. Have you anything to say with regard to the testing of very low resistances?—There is one point I have made a note of, which is commercially useful, and that is the testing of the insulation resistance of specimens of covered copper wire. In the old days, when insulated wire was almost exclusively employed for submarine cables, it was the custom for there to be at the works where the cables were made, and, doubtless, it is the custom still, to have two distinct sets of testers, the one testing on behalf of the contractors, the manufacturers of the cable, and the other testing on behalf of the future owners of the cable. They had separate instruments, separate rooms, and they had two staffs, who tested their own instruments, and assured themselves of the accuracy and so on. Now, at the present time, insulated wire is very largely used, of course, for other purposes besides submarine cables. Last year alone, for example, the cable made in this country for other purposes than submarine cables cost a little short of a million sterling, over £900,000. This insulated wire has stood in instrument makers' catalogues as having a certain quality. For example, it is stated in this catalogue: "The vulcanised cables and wires in the following price list are subjected to a searching electrical test before being sent out of our factory. This test, with a battery having an electro-motive force of 600 volts, is made after the cable has been immersed in water for at least twenty-four hours. A label is attached to each coil, giving the minimum insulation resistance in megohms per mile at the end of the first minute's electrification at 60 degrees Fahr." All that is perfectly clear and intelligible to an electrical engineer. We would suppose an engineer who is not dealing with submarine cables, say, who is at an electric light station, or at a power station, and who orders some of these cables. He, of course, presumes that they have passed that test, and have that standard. Unlike the staff of the owners of a submarine cable, he, as a rule, has no means whatever of ascertaining whether the insulated wire he purchases has, or has not, the quality stated here; he has no laboratory with delicate instruments. He may, of course, go to the factory, where the insulated wire is made, and may see certain spots of light move about and be told that means so and so, but unless he has time and opportunity to test the instruments themselves, and then assure himself of their accuracy, that is no use. He may just as well take the makers' statement as representing the quality of the cable.

In connection with electric light work, for which I have often specified, I have brought one or two specifications of my own, containing a clause which I have over and over again used in connection with the insulation of wire, I do not ask that it should be tested as high as an electro-motive force of 600 volts, but I have contented myself with 110 volts; but as regards the rest, I have required that: "The insulation resistance of any conductor other than a flexible cord"—that means the twin wire—"when tested in water at 60 degrees Fahr., after twenty-four hours' immersion, is not to be less than 2,000 megohms per mile after one minute's electrification, at a potential of 110 volts relatively to the water." That is to say, I have said, that the wire is to fulfil practically the specification which I read out of the manufacturers' catalogue, when tested with rather a smaller battery power, that is when tested in not quite so severe a manner. (*Exhibiting.*) What is the result? It has been presumed that I should not test it—at least I should suppose so; but I have gone on the other plan of testing specimens of every coil submitted, and I find that while some is two and a-half times as good as I specified (and here is a sample piece which I cut off, which has 5,000 megohms per mile, I only asked for 2,000), other samples have one-sixth or one-seventh of the insulation I required. As far as the insulation resistance of the wire is concerned, if it had been only two-fifths as high in the first case I should have been compelled to pass it, whereas if it had been even six times as good as this specimen possesses I must have rejected it. I presume that they assume that the consulting engineer has no easy means of testing, and there is no public place to which he can send it to have it tested, and therefore the statements, I am sorry to say, in the cable manufacturers' catalogue, some of them—of course, there are exceptions—have become practically meaningless. My specification for the twin wire differs. Instead of making it for 2,000 megohms, I say, "The insulation resistance of twin flexible cords, when tested in water at 60 degrees Fahr., after twenty-four hours' immersion, is not to be less than 300 megohms per mile after one minute's electrification at a potential of 110 volts relatively to the water." Exactly the same sort of thing has occurred there. *This* wire is eight times as good in insulation resistance as my specification. *This* wire, supplied under exactly the same specification, is only one hundred thousandth as good as asked for, and supplied under identically the same wording of the specification. What I find now happens is that they supply, perhaps this (*producing a specimen cord*), and then I reject it, and they say they are extremely sorry. And then another specimen is supplied. *This* is only three-hundredths as high as it ought to be. Then they give up all hope of passing this sort of stuff, and people go to Messrs. Siemens, or some other good manufacturer. This was got from Messrs. Siemens, and I am not saying it as a matter of compliment—they go to an honest manufacturer,

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and you get wire which is several times as good very often as you asked for originally. This (*exhibiting cord*) is 2,400, and I only asked for 300; it is, therefore, seven or eight times as good as I asked for. That is what you may get—this is the actual fact of my experience within the last few years in connection with the several specifications in which those clauses are given. My experience is that wire will be put up in the building which is being wired—a public building in this case—which, if you say nothing, and do not test it yourself, may be only one hundred thousandth of the insulation of what you ask for, whereas there is wire in the market, which can be obtained, which is two, three, four, five, six, and seven, and even eight times in this case, as good as I have asked for. Clearly, I do not know what consulting engineers, who have not the advantage of a very well-fitted electrical laboratory like myself, could do; I suppose they accept the material on trust, and that may be one of the reasons why such bad electrical work is done.

2002. Then you think that testing is most important in this case?—Yes; a person who has not a laboratory like my own to send a piece of insulated flexible cord like *this*, or *that*, should, for some small fee, be able to get the insulation tested for him, and there should be some means of ascertaining on behalf of the public, because, ultimately, it is on behalf of the public, whether the statements in cable manufacturers' catalogues are true or only purely imaginary, as many of them are, I fear, at the present time.

2003. Perhaps you will now pass on to the third of our terms of reference. Have you considered the desirability of the establishment of a laboratory for the determination of physical constants?—Yes; I have looked at the terms of reference. There are various constants which are very doubtful and yet which are in regular use. There is a constant, for example, which gives the value of the specific heat of super-heated steam. Regnault made experiments on this, and found that between 225 degrees centigrade and 125 degrees centigrade at atmospheric pressure it was .48, and this value is commonly used for all pressures and temperatures. But it would appear that for the specific heat of super-heated steam, according to Regnault's experiments, between 125 degrees cent. and 100 degrees cent., .38 may be correct. Well, now, there seems to be very considerable doubt as to whether that value holds at other temperatures. Indeed, even between 125 degrees centigrade and 100 degrees centigrade it is a question whether the value is more nearly .38. Of course, that is a very large difference, 10 parts in forty—and whether lower down in temperature the number is not lower still. Now, this is a constant which is of very considerable importance to engineers in connection with the testing of steam engines. The engine is specified to produce each horse-power for an hour, with a certain consumption of steam (allowance being made for wetness of steam) at a certain pressure. The test is made, and the specification being rather severe—we want to get the engines as good as possible—it is very often a question as to whether the reason why apparently rather more steam has been used than ought to have been may not have arisen from the wetness of the steam. The steam has to be tested for wetness. One of the best ways of doing that is to let a little steam come out through a small nozzle, through a fairly non-conducting stopcock, into a chamber lined with a substance which does not let the heat go out. It becomes superheated rushing through the stopcock, and if we know the specific heat of superheated steam under those circumstances, we can then determine how much water there was in the steam, and, therefore, whether the engine not doing what it ought to have done arises from the boiler not quite doing its duty. But if there is any doubt, and I think there is a great doubt about this constant, then a very large sum of money will depend upon it; the engine may be rejected or passed, or *vice versâ*. Discussing the question of the specific heat of superheated steam with Professor Perry, he agreed with me that there was certainly considerable vagueness in that very important constant used every day.

I have also discussed such points with Professor Smith and other engineers. Questions arise again with reference to the conduction of heat between solids and gases, and between solids and vapours, the passage of heat through boiler plates—that is to say, the facility with which the heat can pass through the boiler plate to the steam inside—it is a very important question. The way in which the heat can or cannot be given up by the surface of the boiler plates to the vapour in contact with them, the way it passes between metal and liquids, is a very important question. In warming we want the heat to pass, but there are other cases where we want to keep a building warm, where we do not want the heat to pass. Generally, the loss of heat for heating buildings, the non-passage of heat—what determines that is very important. In fact, you may say, in connection with heat there are many problems which are of very great importance to engineers to-day the solutions of which it would be within the power, and certainly within the province of such a National Physical Laboratory to provide us with.

2004. Generally speaking, do you think that experiments in a laboratory, such as is proposed, would be sufficient to solve the problems?—There would be some problems that it would solve, but there are other problems where I do not think it would. For instance, I have here a note with reference to the resistance which, say, the air offers to trains; that would not be of much use unless the result was ascertained on a large scale. Wind pressure on bridges, houses and other structures—I think that would have to be done on a large scale to give results of engineering value. I do not know, however, that it would not be within the province of the Laboratory to send out expert testers to assist in making experiments. If I am not wrongly informed in connection with the Meteorological Council, it now does send out people to find out when apparatus has gone wrong, and there would be a precedent for experts being sent out on request from the Laboratory to supervise or assist in making such experiments. On the other hand, of course, there are many experiments which could be made within the walls of the Laboratory, which, also, would be of great value to engineers and the world generally.

2005. Do you think, in general, that the National Physical Laboratory would aid in the commercial development of the country?—I think it would very materially aid in the development of the country. It would aid in making public, by giving to the country, information of general use which now, if obtained at all, is obtained by an individual manufacture solely for his own benefit, and if another manufacturer wishes to obtain it, he has to go through the whole experimenting processes again. It might, at first sight, be said, that the first man should patent the process, and the others could use it, paying a royalty; but there are many results which, although obtained at considerable expenditure, and as the result of great labour, which are of great value to an industry, cannot be patented. The patentee is simply telling other people how to use them, and those at present have to be kept secret. That, naturally, is a very troublesome fact, and it rather deters manufacturers from carrying out such experiments. They feel this: "If we carry out the experimenting it will be a lengthy and expensive affair, and we cannot patent the result when we get it, and it will be extremely troublesome to keep it to ourselves." An instance is better than generalities. In connection with an experiment I made myself, I found that one of the reasons why a certain well-known form of a galvanometer could not be increased in sensibility, was because the coil of silk-covered copper wire was magnetic, and, therefore, that if it were non-magnetic, the galvanometer ought to become much more sensitive. A small current gave a certain deflection, and as you increased the strength of the magnet the sensibility of the galvanometer ought to have increased, but that did not happen, and as the magnet became stronger, at a strength greater than a small value, the sensibility went down again. I saw that was due to the substance of the coil, although no iron or steel was in the coil, being magnetic, and the question was to find out how that was to be avoided; it was a lengthy experiment. Ultimately, one was successful, and, without wishing to boast, the result has been that one has been able to increase the sensibility twenty times, but it would be very difficult to obtain any pecuniary benefit from such an investigation. Of course, that is what a manufacturer must look to, but as the coils of the galvanometers which have this high sensibility look exactly like those of other galvanometers which have not, it is impossible to tell whether the particular device has or has not been employed. Patenting is useless, and yet if anyone be taught to use the method under my instructions, what is to prevent his going and giving the information to any maker of galvanometers? There are many cases of that kind, and the only way in which those things are to be preserved at present is by assuring secrecy, to prevent workmen going about the factory too much. But it would be far better that such information, so obtained at the public expense, should be given out for the benefit of the public.

2006. Do you think that the manufacturers should be allowed to consult the Laboratory officials confidentially, or that all the work done there should be published?—

I am inclined to think that it should be all published, that a public laboratory should be for the benefit of the public, should be supported by the public money, and the results obtained should be for the benefit of the public. Therefore, I think that there should be regular reports given to the public of the information that is obtained.

2007. Have you any opinion as to the best site for such a laboratory?—Kew has been, of course, suggested to me. It has advantages in being at a certain distance, and not too great a distance, from London; being removed, more or less, from the traffic; at present it is not suffering in any way from that, and I hope it will never suffer very seriously from electrical disturbances. Therefore, Kew, if there is sufficient room, would be a site to suggest itself to a resident in London.

2008. Do you, as an expert, consider that a very small amount of electrical disturbance would ruin the site for experimental purposes?—For many experiments it would ruin it.

2009. Have you formed any opinion as to the constitution of the council by which the Laboratory should be governed?—I am inclined to think it would be very desirable that the more important technical societies should have a direct representation on the council. Clearly, of course, the Royal Society, the chief scientific society of our country must be largely represented; but I think it would be desirable that certain of the more important technical societies should, as I have said, have representatives on the governing body, because it is very important that the experiments that are made should be those that an engineer, in many cases at any rate, would desire to see made. I know there would be a kind of fear, and that is why I mention it here, if the Laboratory were thrown open to the public, so to say, that there would be an overwhelming amount of problems forced on to the Laboratory to solve, but that is not the way engineers go to work. They are not merely anxious to carry out research because they like experimenting; they only carry out a research when they want to know the answer, and, therefore, the fact, supposing it should turn out to be the fact, that the important engineering societies were directly represented on the governing council, will remove the fear of this overwhelming amount of work being thrown upon the Laboratory, and will assure the public that everything done in such a Laboratory is done for the public good, and there will be no question or cavilling on the part of the public as to whether this or that investigation has any real commercial or public utility.

2010. (*Sir Andrew Noble.*) You have given such a clear exposition of your views that I have hardly any questions to ask. If the advisory council or governing body, such as you have described, were formed, you think, I suppose, it would be their duty to advise the Board of Trade when required, and from time to time to examine their standards?—Certainly.

2011. Then you have regard, also, to the great convenience of the public being able to have various instruments, and so on, standardised. If they were sent in by private manufacturers there would be a reasonable fee paid, I suppose, so that that part of it might be self-supporting?—Yes; there is no reason why, just as at present fees are paid to Kew for testing chronometers and thermometers, fees should not be paid for testing the specific things, like eye-glasses, and, naturally, a definite fee.

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2012. Then you alluded to certain standards of light. Naturally, one asks the question upon a point where you have known considerable disputes arise, such as, for example, a search light, when it is specified that it shall be 20,000 candle power, or something of that sort?—Yes.

2013. You know there have been, frequently, very considerable disputes upon that subject?—Yes.

2014. That is, the test is of a nature that could be carried on by such a laboratory?—Yes, in that case. That would be one of the cases where the Laboratory would send, or might conveniently send, a man to the place where there was a search light, and the engine, and the dynamo. The man would go; he would take his photometer, and his standard of light, but it would be for the people who wanted the thing tested, the Government or the commercial firm, to supply the light and run the dynamo, and that would relieve the Laboratory of a considerable expense, and at the same time the light would be there in the conditions that the makers of the light would wish it. Instead of sending the search light, which is a large affair and requires much power to run, to the Laboratory, that it what I should do. If people wanted me to give an opinion as to whether a search light did or did not comply with the specification, I should go to the place where the search light was, and should not ask them to send it to my Laboratory.

2015. (*Mr. Roberts-Austen.*) As to the question of alloys; as a matter of fact, was not manganin at first devised in Berlin?—Yes. In 1891, when I went to the Frankfort Electrical Exhibition, I was quite surprised to find all kind of resistances, commercial resistances, on exhibition, made of manganin. I had no knowledge of manganin, and I had never seen it before. Dr. Lindeck was good enough to tell me all about it at the time; and he has supplied me with information subsequently. On my return to England in the autumn of 1891, I mentioned the matter to a number of makers of resistances in London, and many of them, like myself, had never heard of it. One that had, said that he knew about it, and that it was no good whatever. The idea that manganin is not a very stable substance still exists in this country, and, I think, arises partly from want of experience and partly from want of knowledge of how to use it. I have here a letter recently received from Dr. Lindeck, written spontaneously, and not in response to a letter of my own, about this very subject, in which he speaks of standard coils; they have numerous practical standards now at the Reichsanstalt, and they are made of manganin, and in six years they have not varied one or two thousandths per cent., that is, not by one or two parts in a hundred thousand. These resistances are, I think, something like the standard resistances sent to the Board of Trade from Berlin. I believe they are made of manganin, whereas a not uncommon feeling in this country is that manganin is of no use.

2016. Do you think all such questions, although considered by the Alloys Research Committee of the Institution of Mechanical Engineers, might still be entrusted to such a Laboratory?—Certainly.

Mr. William Henry Preece, C.B., F.R.S., called; and Examined.

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2017. (*Mr. Rücker.*) You have been a member of the British Association Electrical Standards Committee since 1877?—Yes.

2018. You have also been a member of the Paris Congress of 1881-3, and of the Board of Trade's Committee of 1892?—Yes.

2019. Your professional life has been devoted to the introduction of more exact methods of telegraphy?—Entirely. But I would point out there that the principle I have always advocated has been that of careful inspection and searching tests, both before erection and after erection, and continued throughout the whole period of their maintenance.

2020. Could you give us any account of the steps taken to that end?—I would commence first by saying that the person who really inaugurated this system was Cromwell Varley, and he, in 1859, brought out an instrument called a universal tester. It was a combination of the Rheostat and differential galvanometer, and was extremely useful and handy, and he introduced a really practical unit for the first time. That was based on a coil of No. 16 copper wire of the commercial wire of that period, and, therefore, scientifically, very poor indeed, but it was used for a long time, and it was replaced by the B.A. unit in 1866, and now we are very rapidly introducing the Board of Trade standard ohm, together with the volt, the ampere, and the microfarad and others.

2021. These are found necessary for practical purposes for determining the breaking of cables?—Yes, it was the necessity imposed by the breaking of a cable to determine the distance of the break that led to that.

2022. Could you give us any account of the machinery that the Post Office have at their disposal for carrying out tests of this sort?—Yes, our testing arrangements in the Post Office are very extensive. We have three laboratories at our store place at Mount Pleasant; we have four in our workshops at Holloway; we have two in the General Post Office, one devoted entirely to electric lighting, and the other to telegraphy. We have two ships employed entirely in laying and repairing cables, with store places for cable things, and also we have practically at our disposal at all our large contractors—seven or eight of them—the most complete laboratories that expense could enable them to construct.

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2023. You are willing to hand in an account of the vast number of tests in these laboratories?—I will give you the figures; I have just reduced them to a summary; I thought it much better to give a summary. The numbers are very large. Every day we test, from about seventy or eighty stations, 166,000 miles of wire. Every month, every circuit in the country, numbering about 6,000, is also tested, for resistance and for insulation, with great care. Then there are 156 cables whose average length is thirteen nautical miles, that are maintained in constant test, but the greatest figure that I can give you is that of the Instrument Department. At our works at Holloway we inspected and tested during the year 1897, 105,272 instruments. Of these, 72,533 were tested electrically, with all the scientific care that we could command. Again, at Mount Pleasant, which is our store place, where all stores are delivered, in the same year we tested no less than 730,000 different things, every one of them with the same care; and at the various contractors' works we tested 327 miles of cables, 1,855 miles of Gutta-Percha wire, 1,593 tons of copper wire, and 9,375 of iron wire. In addition to this we have also carried on at my headquarters at the Post Office, in one of the laboratories, investigations in various directions. This popular wireless telegraphy and telautograph (the new writing telegraphy), the synchronograph, a mode of working that has been invented by two Americans, Professor Crehore and Mr. Squier, who have shown that we get great speed by using alternating currents of the Sinusoidal form, and they have shown that we can increase the rate of working quite two or three times. Well, then, I thought you would be interested in seeing the latest thing we have done, and that is the mode of applying the Röntgen rays to visible testing purposes. In addition to the ordinary electric test to determine the electrical conditions of the joints, we can actually see the joints though covered with Gutta-Percha. The Röntgen rays are passed through, and the thing is printed, and it is just like seeing the very thing itself.

2024. You use, then, altogether, a large number of instruments in all these various operations?—Yes. I can give you the numbers, which are equally startling. We have in constant use 128 Wheatstone bridges complete: the Wheatstone bridge means not only the bridge itself, but also the rheostat coils complete, and carries with it a galvanometer. Then, we have volt meters, ampere meters, and galvanometers, 203; rheostats, 74; standard condensers, 10; battery testing instruments, 75. standard instruments for reference, 250; scales, gauges, and things of that kind, 40; switches, 50; 5,000 standard cells; and thermometers and chronographs—making 6,366 pieces of apparatus used for testing purposes.

2025. Have most of those been standardised by comparison with any standard instrument?—Originally, they were all so standardised, but we have never had any means of referring them to a standard authority. We have, once or twice, sent a standard ohm to Mr. Glazebrook at Cambridge, and we have sent ampère meters and such matters to the Board of Trade for standard examination. But, as a rule, we have been compelled to rely entirely on our own comparisons with standards that may have changed.

2025*. I presume you have a large staff employed?—Yes. At Mount Pleasant there are 18; at the G.P.O., 13; at Holloway, 36,—67 permanent officials in all, while 200 others are detailed for morning testing duty every day. Thus there are 267 engaged in testing duties every day, every man employing apparatus that should be standardised.

2026. Is it possible to use the Board of Trade Laboratory more largely than you do now?—Scarcely. The Board of Trade Laboratory has been established for a specific purpose, to comply with the requirements of the Electric Lighting Acts of 1882 and 1888, and it is very complete for that purpose. It has done its work in a very magnificent way; it has secured the confidence of everybody concerned, but it does not go beyond electric lighting apparatus; it does not touch instruments which we use for telegraphy in the Post Office.

2027. You think it wants supplementing by some other institution?—Undoubtedly.

2028. Have you paid special attention to the movement in favour of a National Physical Laboratory?—Yes, I have looked at it very carefully and given the matter a great deal of consideration. There are many things beyond the reach of the Board of Trade and of existing laboratories of a very important character which want to be taken in hand.

2029. What duties would you assign to a National Physical Laboratory?—The testing and verification of instruments for physical investigations generally, apart from the examination of electrical instruments. Then, again, we want a place for the construction and preservation of standards and measurements of all kinds, not alone ohms and ampères, and things of that sort, but in optics and magnetism, and every branch of Science.

2030. You would accept the standards of length and measures of the Board of Trade by Act of Parliament?—Yes, they are also specific under an Act of Parliament and under the Board of Trade, and so I would accept them. We want something for the systematic determination of physical constants and numerical data for scientific and industrial purposes. All our tables and all our note books are extremely vague: they want verification; and there are many things in our own profession; for instance, as you know, the dielectric constant is very little known, and perhaps more than anything else the value of the magnetic permeability (the value of μ) is very little known indeed. There are only very few men—scientific men—who really have made careful observations on that, and it is an extremely important constant.

2031. In speaking as the head of a great Government practical department, you find yourself hampered by the want of physical data, do you not?—I do, undoubtedly, but I find myself hampered more by this, that I and my staff have our time occupied in making investigations and in determining data that ought to be provided for us, and the occupation of our time is a matter of very serious consequence, and of some considerable expense. I think, in addition to all that, a National Physical Laboratory should have some place for individual research. There is many a man who thinks he has got an idea and wants to work it out, and he is entirely prevented from the want of apparatus. Mr. Ludwig Mond, at his laboratory at the Royal Institution, has enabled that to be done in the chemical line, but we want a great deal more in the physical line.

2032. But that is a totally different branch of work from that to which you have been referring?—Quite.

2033. The reason I ask is, that I am not sure whether it is included in our reference?—I merely mention the fact that a place of that kind would ease us of a great deal of unnecessary work, for if everyone came to me, as they do every day—and the number of inventions submitted to me is about three a day—I say it would be a convenient thing for me to say: "Go to the National Physical Laboratory, and they will tell you all about it." Of course, we know that a Physical Laboratory can do what individuals cannot. An individual gets bored, and sometimes loses his temper and is annoyed at what is said and done, and then he cools down; we have seen that done over and over again. But a Physical Laboratory does the work as a duty, and does not do it for enthusiasm nor with a desire of money, nor to gain kudos.

2034. Could you give a list of the physical constants which ought to be more carefully studied?—I have given two important ones as affecting electrical science, there are also the specific resistances of saline solutions particularly. We want that very badly. That is electrical; but there are many other points. There are fusing points of wires, particularly alloys; they vary very much. Here is a case that occurs nearly every day:—A place is fitted up with the electric light; it is well fitted up with fuses, and one fine day the whole place is put in darkness, because a fuse has gone. We do not know why. It goes with a much less current than it was designed to carry, and yet it goes in consequence of some change in the character of the alloy, or even pure metal it may be—which wants investigation.

2035. With regard to the necessities of your own office, such as examination of air in pneumatic tubes, and matters of that sort, what have you to say?—There is no data available on the subject. We have for some months, and at large expense at one time, been occupied in determining the laws that regulate the flow of air through those small pneumatic tubes under compression and under vacuum.

2036. Then you want an Institution for the purpose of determining the heating of conductors and the fusing points of wire?—Yes.

2037. Are there any other special points in which you are now engaged commercially which are really outside your particular work, and which ought to be entrusted to someone else?—I have been engaged in a good many things. For instance, one thing which took up a long time is a proper testing for glow-lamps. But at the present moment I am investigating aluminium for electrical purposes. Aluminium is produced in large quantities, and it is very strong and very light, and seems as though with the same electrical resistance and

the same mechanical strength we can lighten wires on our poles very considerably, and thus increase the number that a pole can carry, and so make our main roads bear twice as many wires as they do at the present moment, so that it is a very important economical question. Then we have several insulating media, new accumulators and batteries, and oils, and lubricants of all kinds, and always a dozen or more new lamps under investigation.

2038. Putting it generally, you think the Post Office would have a number of questions which they would be glad to refer to a National Physical Laboratory?—Unquestionably.

2039. Would the Post Office be prepared to pay fees to the Laboratory for such work being done?—Certainly.

2040. You do not think it would be necessary that, if this National Physical Laboratory were started, it should do the work for Government institutions for nothing?—It is unfair; but I must confess that that work is done by one Government department for another for nothing.

2041. And in this particular case, it would be difficult to maintain the precedent?—In this case, we have the precedent of the Chemical Laboratory; they test all our materials for nothing.

2042. Obviously, in that case, there would be some limit to the amount of work, or there would be no limit to the Government money?—It means, I think, the Treasury should take credit for the work done by the National Physical Laboratory for the Post Office.

2043. You think that either the place ought to be paid or that it would be a fair argument to use to the Government in favour of the establishment of a laboratory that Government work would be done in it?—Certainly.

2044. Do you think that there is any demand for a Physical Laboratory at present?—A very considerable demand. I do not charge any fee for the work I do at the Post Office to anyone, and I have often done work for outsiders quite independent altogether of the work done for the Post Office, if there is the slightest chance of the thing submitted to me being of any use to the Post Office.

2045. Do you think that such a laboratory might be a paying thing as a commercial enterprise?—Yes.

2046. Then, in the next place, I should like to ask a question with regard to the work sent in to the Laboratory—ought the results to be published, or should manufacturers be able to consult the Laboratory authorities confidentially?—I think it ought to be published. I cannot give you any good reason for saying so. It may be, of course, if things were kept secret you might acquire a greater income by people coming and consulting you, but in a public department, supported by public money, the results ought to be given to the public.

2047. Do you think an institution of this kind would be largely self-supporting when once started?—I think so.

2048. But you would think a certain amount of funds is necessary to start it fairly?—As a matter of security, one would like to see a place of that kind at starting endowed, and if we can only inculcate in this country the sort of feeling that obtains in America—that is to instil a little scientific patriotism into our millionaires—we might get someone to make handsome endowments. If we had a few Gassiots they would be very useful units.

2049. Have you formed any idea as to the best site for a Laboratory?—I do not think you can improve upon Kew. It is convenient, it is undisturbed, and it is handy, and it has one great advantage—that there are not many people there. If it were in town you would be worried by people going there.

2050. I dare say you have seen it stated that at a distance of a mile and a-half from Kew there are to be electric tram lines?—I have seen that.

2051. Do you think it would be possible to preserve Kew intact from such disturbances?—I think so. I have also seen it stated in the American papers that with the perfection of rail returns that they adopt now they have completely cured those disturbances. At the present time we bond our rails and lay between them a bare copper return wire, and ought to make a complete metallic circuit.

2052. You think, by one means or other, the difficulty could be overcome?—I think so.

2053. Now, as to the management of the institution, what have you to say?—I do not think a better example could be given than the working of the Kew Committee—a committee nominated by the Royal Society, with representatives of industry and of commerce and technology, supplemented by an able chief, who must be a very well selected man.

2054. Do you speak as a man having close relations with industry and technology, when you say that a council or committee nominated by the Royal Society should be appointed as the governing body?—Yes.

2055. You think that the members of the Committee need not all be Fellows of the Royal Society, but that industry should be largely represented?—I think so. I have perfect confidence in the Royal Society that they would gladly conform to anything of that kind.

2056. Have you formed any opinion as to what the salary of the Director should be?—No.

2057. I presume you think we ought to have a man of fairly first eminence?—Undoubtedly.

2058. And, therefore, you would want to attract him from a good post?—Yes.

2059. And, therefore, he must be well paid?—He must be well paid. You could not get a man competent to take charge of that under something like £1,500 to £2,000 a year.

2060. Then, I should like to ask you one or two questions: In the first instance, do you think there would be any risk of the Laboratory being so overwhelmed with applications for work that it would be impossible to make a choice of the various subjects, or do you think that the governing body could be competent to do that? I think that the governing body would be competent to restrict the number of cases for the Laboratory to enquire into; and I doubt much whether the number of cases submitted would reach anything like an overwhelming number.

2061. Do you think, on the other hand, that this work would at all interfere with that of the private investigator?—Not at all; the private investigator generally goes to work from mere enthusiasm: he has his own apparatus and his own place. It would be rather the place for the relief of men like myself, whose time is occupied with other things.

2062. Then, you think that there is work that could be carried on by officials which would not interfere with the work of private investigators?—Certainly.

2063. (*Sir Andrew Noble.*) Of course, private individuals would come to the Physical Laboratory for assistance in their own investigations, should they require it?—Yes; but a private investigator would sooner use his own apparatus as an amusement.

2064. But there are certain things which would be undertaken by the Physical Laboratory, which either from the length of time required, or other causes, could not be undertaken by a private individual?—That is my argument: They lose their time and they lose their temper, and they drop things.

2065. (*Mr. Roberts-Austen.*) You were mentioning the case of fuses going off with smaller currents than they are expected to carry. There was a case of Manganin zinc alloy, which was largely used for binding screws, do you mean that?—Yes.

2066. That was found to disintegrate, and fell to pieces in ordinary use. Is that typical of many cases that would require investigation?—Yes; we have sent three or four to yourself.

2067. And such questions would naturally be investigated in the National Physical Laboratory?—I think so. This fuse question is one of the most important questions of the present day.

2068. You want it for the purpose of investigation as to the molecular change in the wire?—Yes; we had one of our places at the Post Office last week thrown into darkness for several minutes.

2069. And little is known as to why those wires disintegrate?—Yes.

2070. You are familiar with the Alloys Research Committee?—Certainly.

2071. Have you formed an opinion as to the interest of that committee?—Yes, and of its value also, but this is just one of those points that would not come to the Alloys Committee. It is a question of a particular kind of molecular current passing through.

2072. Speaking generally of the work of the Alloys Committee, would you say that it should be entrusted to the National Physical Laboratory?—I think so.

2073. (*Mr. Siemens.*) I would like to ask about these fuses. You are not aware that all fuses which are constructed according to the Fire Insurance Companies' rules must go in the way you say, because we have had a long investigation about that, and no fuse will hold which cannot stand double the current, double its normal current for a few minutes, and the Fire Office rules prescribe that it must go with 50 per cent. more?—Quite so.

2074. And it will go after some months?—Of course, my point is this: that if you take a fuse which complies with the Fire Insurance regulations, and complies with all the tests that we give it, after it has been up for two or three years it has lost its properties, and does not then comply with the rule; and we only find that out when the building is in darkness.

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2075. (*Mr. Roberts-Austen.*) They appeared to be perfectly sound when made, and it was only after some little time that they fell to pieces spontaneously?—Yes.

2076. (*Mr. Siemens.*) You said that all investigations ought to be public property, because the Laboratory is supported by public money. Could not you allow of secret experiments, I mean for the benefit of one person, being made by his payment of extra fees, and would that not come to the same thing?—I have not seriously gone into that point, but I simply say that it ought to be public, because it would be supported by public money, and the public would cry out if secret operations were going on there.

2077. You have said that you are of opinion that the Board of Trade Bye-Laws about the returns of electric tramways are quite sufficient to protect an institution?—When fully carried out.

2078. I do not know about the head of the institution—do you think that a professor is the best?—No. I should like to put this down strongly; I think the head of this establishment should certainly have had some training in the practical world; he must be a scientific man, but he must have had practical training to understand all the requirements of the practical world. I think a mere academical professor put at the head would not be received with the same confidence as a practical man would.

Wednesday, 9th March, 1898.

PRESENT:

Mr. A. W. RÜCKER, D.SC., F.R.S. (in the Chair).

Sir COURTENAY BOYLE, K.C.B.
Sir ANDREW NOBLE, K.C.B., F.R.S.
Mr. W. C. ROBERTS-AUSTEN, C.B., F.R.S.
Mr. ROBERT CHALMERS.
Mr. ALEXANDER SIEMENS.
Dr. T. E. THORPE, F.R.S.

Mr. L. BLAIKIE, *Secretary.*

Professor A. B. W. Kennedy, F.R.S.
9 March 1898.

Professor ALEXANDER BLACKIE WILLIAM KENNEDY, F.R.S., called; and Examined.

2079. (*Mr. Rücker.*) You have been appointed by the Institution of Mechanical Engineers to attend this Committee to give evidence?—Yes.

2080. You are Past-President of that Institution?—I am.

2081. You are aware of the general outline of the scheme for the establishment of a National Physical Laboratory?—Yes.

2082. Have you given any attention to the subject?—Of course, I have thought a good deal about it.

2083. There are three points in the Terms of Reference to this Committee; the first is that we should "consider and report upon the desirability of establishing a National Physical Laboratory for the testing and verification of instruments for physical investigation." Have you any information to give us as to whether that is desirable or not?—Do you mean in reference to mechanical engineering.

2084. We put no limitation upon the point, but if you choose to adopt that view of referring only to mechanical engineering, we must take you on that?—Quite so.

2085. (*Sir Courtenay Boyle.*) There are plenty of instruments for physical investigation that you must be cognisant of?—I do not know that I have any right to speak as to physical investigation. As to engineering, the only instrument which occurs to me as important with regard to official verification, would be the springs used in steam engine indicators.

2086. (*Mr. Rücker.*) Do you think that there is room for an Institution in which such instruments should be standardised?—If such an Institution were established I have no doubt it would be used for that purpose. At present one has to standardise them for oneself, and one has to fit up one's own apparatus, and it is rather a nuisance.

2087. Do you think that the makers' guarantee as to the accuracy of such things is sufficient, or is it desirable that it should be supplemented by the tests of an Institution such as is comtemplated in our reference?—I can answer that best by saying that I do supplement by tests of my own, but I should not make my own tests if they could be made by the Board of Trade, for example. I might add with reference to the verification of electrical instruments by the Board of Trade, that seems to be a very great deal made use of; but I believe that many people who wish to verify such instruments, and to be very careful to verify them, prefer to do it in place, and to use their own standards. I have a great deal of verification to do every year, and I have to do that in the place where the instruments are, partly because I cannot spare them to go out—I want them—and partly because they are apt to be a little altered if knocked about.

2088. What instruments do you refer to now?—Both ammeters and voltmeters. Of course, it is very useful to get some official certificate of those when they are new, and that is something; and that is a thing which would be done by this Institution if it were established. It is a thing that we have hoped to get from the Board of Trade. I may say that, unofficially, the Board of Trade has helped us very much in the matter, as Sir Courtenay Boyle knows. But the greater part of the tests—at least ten tests to every one of the other, we have to do *in situ*, and we do not send the instruments away.

2089. But if you had a standard instrument by which the others could be compared, it would be useful to have that compared and standardised?—Yes, one can get standard instruments of a sufficient accuracy for that already; take the Kelvin balance, for instance, that under ordinary circumstances is accurate enough as a standard.

2090. (*Sir Courtenay Boyle.*) The value of the ammeter would depend on how it was placed, would it not?—Exactly so, and therefore we could not send it out to be tested.

2091. (*Mr. Rücker.*) Now I pass on to the second point for consideration, "as to the desirability of establishing a National Physical Laboratory for the construction and preservation of standards of measurement." Do you think there is anything to be done in that way?—Not so far as I know. You mean such measurements as linear measurements?

2092. I mean any measurements useful to mechanical engineers?—No, I do not know of anything in reference to that.

2093. Then we have to consider the next question as to the "systematic determination of physical constants and numerical data useful for scientific and industrial purposes." Do you think that there is any work of that sort which could be better done by an official Institution than by the private worker?—I read this part of the reference very carefully. As to scientific purposes, I do not feel that I should speak of them. For industrial purposes I do not feel that there is likely to be more use coming from an official establishment than from present sources, such, for instance, as the Mechanical Engineers' work, of which I naturally know the most, except in the particular matter that purely scientific experiments very often have, of course, the greatest influence on industrial matters, although to begin with they may be apparently purely abstract and have no industrial value. Putting that on one side as a matter on which I should not say more, but speaking rather of things that are obviously technical, I do not think really that they would be better done, probably, by a central official institution, than, for instance, by our committees at the Mechanical Engineers. I do not know whether it is necessary to say anything about that.

2094. It has been before us, and, perhaps, Mr. Roberts-Austen would ask you some questions on it?—As a matter of fact we have spent something like, I believe, £4,000 or £5,000 over it. We have had seven or eight Com-

mittees, and the investigation has in every case been actually conducted by some man of scientific position or eminence, more or less. One of our most important experiments has been conducted by Mr. Roberts-Austen himself, but it has been conducted under a Committee of technical people, supposed to know what points they want to know about, and the Committee has been different in each particular case, and we have drawn upon our own members and upon other people for those Committees. The Committee says what they want, and the experimenter does his best to find that out in his own way. Of course, in the case of Mr. Roberts-Austen, he has been left to himself, naturally, as he knows more about it than the Committee; but in the case of riveted joints and marine-engine trials and experiments on friction and other things, the Committee had a great deal to say. They met often, and made many suggestions, and controlled the whole course of the work, although they got the best man they could to do it. That has worked very well, and I cannot say that it would be done better by a central institution.

2095. Have you any laboratories where it could be done?—Where a laboratory has been wanted we have made use of a laboratory at some college or other.

2096. That is to say, it has been a matter of grace to allow you to use it?—That has been a matter of grace. But most of the work has not been laboratory work. For instance, I think there was an important series of trials of riveted joints; they all required testing by machines of the very largest size, and they were done at different works in the country. The experiments on marine engines, of course, were made on the steamers; the experiments on friction were done at some works where our own machines were put up; the experiments on gas engines, which are being carried out now with reference to gas-engine theory, are actually being done at Birmingham at the Mason College, but that is because our reporter happens to be the professor there.

2097. We may take it that there will be always a proportion of the problems which you desire to see solved, which would be attacked in the laboratory?—Certainly.

2098. And the question is whether, or not, it would be desirable that there should be a National Laboratory always under proper supervision of technical experts, where such work could be carried on?—I confess I feel it very difficult to see how the technical influence would come in there.

2099. Possibly by the representation of technology on the governing body, and by Committees being formed in the same way as by the Mechanical Engineers?—Perhaps that plan might do. The governing body of those institutions is generally a very honorary sort of thing, as far as I know. You put on the Presidents of certain distinguished institutions, *ex officio*, and they come *ex officio*.

2100. The nearest approach to it is the Kew Observatory Committee; have you served on that, or are you conversant with it?—I only know that it is very useful for the purpose of having thermometers tested.

2101. It is not my business to give evidence, but members of the Kew Committee have done a great deal of work for the Observatory?—Of course, I am thinking really of engineering matters, as no doubt you will see.

2102. What I wanted to clearly put is, that while you think, there are certain technical matters which can be done on a large scale in a great workshop, you think there are others which can be done in a separate institution?—I think so.

2103. Have you gone into the question of the relations between such an institution if established, and other bodies, which at present do standardising work?—I have not, because I have not really known at all what the proposals were.

2104. Then the last question is one we put to most of the witnesses, namely, whether they consider, if such an institution were established, it would be a convenient method of governing it, that the Royal Society should be the body which directly controlled it, but that the actual governing body should consist, not only necessarily of Fellows of the Society, but also of representatives of technology, and that there should be committees appointed, on which technology could be largely represented; do you think that such a scheme as that would work?—I do not wish to express any doubt about it, but it is a very important matter to give an opinion upon, and I have not considered it.

2105. You have hardly given sufficient attention to it, perhaps?—I have not heard at all until this moment what your idea was about it.

2106. (*Sir Courtenay Boyle.*) We are to enquire into the construction and preservation of standards of measurement; is there any difficulty so far as you find, in ascertaining what are the standards of measurement now; in other words, is not the Standards Department of the Board of Trade sufficiently accurate in its determination of standards, to satisfy the requirements of the trade?—It is quite as accurate as my profession requires.

2107. For instance, a standard yard, a standard pound, a standard cubic foot for the measurement of gas, are properly constructed and preserved in the Board of Trade at present?—I believe so; I have never found any difficulties.

2108. So far as the construction and preservation of standards of measurement are concerned, are not there numbers of standards, the excellence of which is very important to the industrial community, but the excellence of which cannot be ascertained now on authority? Would you say that that is a true proposition with regard to electrical instruments, mechanical instruments, and mechanical appliances?—Yes, which cannot be ascertained by public authorities.

2109. By any public authority?—By any public authority.

2110. And cannot be ascertained except on the investigations of such gentlemen as you can select, able men, but not men having any Government recognition?—Quite so, not men having any Government recognition.

2111. Take the case of marine engines, are there not many questions in the construction of marine engines which it would be easier for marine engineers and ship builders to solve if they had some authoritative body capable of determining certain facts, say, with reference to copper tubes; you know the behaviour of copper tubes in marine engines is extremely open to argument; would not it be useful to have a body to determine authoritatively what is the behaviour of copper tubes under certain circumstances?—So far, we are satisfied with the Board of Trade; we look to the Board of Trade and they are very helpful to the public in general, and the Board of Trade Inspectors do the testing of the copper pipes.

2112. But in this instance, the Board of Trade have to act upon the advice of experts who have not got laboratories, who have no opportunity for experimental investigation, and can only rely upon experiments conducted in actual practice on board the steamers. Would it not be desirable, say, at Kew, to have a body capable of determining the behaviour of copper tubes or the behaviour of water tube boilers?—I would rather trust one of your inspectors than anyone at Kew, or any body of the kind, in questions concerning water tube boilers.

2113. But why would you do so, when our officers have no laboratory capacity?—But they have engineering knowledge. I do not say it because I know that you are connected with the Board of Trade, but I would sooner have the statement of men who have looked after boilers, and who know what they look like when they leak and give way, than have the testimony of any number of people who have made an experiment on a boiler.

2114. Is it not very desirable to know what tube boilers can do under stress, and under certain circumstances which can be produced?—Of course, it is desirable to know as much as possible, but I do not feel that this is the thing that I should like to be done except on the boilers and by men who are technically conversant with the matter.

2114.* Are laboratory experiments of no use in this class of question?—Not except at the initial stages in determining the best copper for pipes, how it is affected by heat, and what is the best iron and steel to be used—those are laboratory questions; but the strength of the tubes when made, or the strength of the boiler when made, I do not think is so.

2115. Take copper tubes—is not the behaviour of copper tubes a subject which could be investigated very largely in a laboratory?—I have no doubt that it could; but I should not attach so much importance to that investigation as I should to a test by a man accustomed to test work of that sort.

2116. I do not know whether marine engineers have very much necessity for employing thermometers, but take thermometers—is there anybody in this country who could test the behaviour of thermometers and verify them in the sense almost of standardising thermometers?—Of course, we all use Kew for thermometers—I wish engineers would all verify their thermometers, but as far as they do, it is most useful.

2117. You would take their test as sufficient?—Yes; for our purpose we have no reason to go behind Kew.

2118. (*Sir Andrew Noble.*) There are a few points where, I suppose, you will admit that a laboratory such

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as is being contemplated under the direction of a governing body such as the Chairman has mentioned, might be useful? Take, for example, the question of tubes for boilers; there is a class of tubulous boilers that are coming into great favour just now; it would be a point of great importance, would it not, if you got those tubes made of a metal which altered as little as possible with changes of temperature?—Yes, that would be so.

2119. There is another point of great importance; if an alloy should be discovered that under the action of the great heat to which they are subjected, would scale as little as possible, I think that would be a case, would it not, where the Physical Laboratory under superintendence we suppose, might give very valuable information to engineers?—Yes, that is what I meant in stating to Sir Courtenay Boyle that the actual nature of the material, and its qualities and suitabilities for special purposes were clearly a matter for laboratory investigation.

2120. And would be of great value to marine engineers and the country generally?—Yes.

2121. Then there is another point. Is not it desirable that with respect to such instruments as pressure gauges for steel boilers and gauges also that are used for determining the indicated horse power, there should be an authoritative place, as Sir Courtenay Boyle has put it, where those instruments could be sent and verified?—I have already said, I think before you came in, as to the steam engine indicator springs, that certainly is so. Also as to pressure gauges, no doubt we all have to test our standard pressure gauges; most of us have to keep a standard gauge of our own, which we test against a mercury column. Of course, as you know, the actual steam gauges may be right when new, but they tell lies afterwards, and you cannot take them off and test them. You are referring to a test of that standard, are you not?

2122. Yes, to a test of that standard?—I have no doubt it would be convenient to have a place where one could get one's own standard instruments tested.

2123. One more point I wish to ask you upon, because I have experienced the inconvenience of it myself, and that is in the case of pyrometers. You know there are several kinds that are used for various high temperatures, and which are coming day by day more into use; some vary from use and from time, but is it not very desirable that you should be able to have your standards occasionally verified by some public authority, and would not a Physical Laboratory under the control that has been defined, have a very useful effect?—If the department existed, I, personally, should, of course, send my electrical thermometers, or other instruments of that kind, there to be verified; but I am afraid if you come to the number of engineers who possess those instruments, as I do, you will find there are very few. I have those things, but I must not be taken as a fair average sample.

2124. But at the same time, I am in that unfortunate position, too?—I know that.

2125. We are using a good number of these instruments, and there are serious questions raised even by the Government itself as to the accuracy of the instruments, and if we had an authoritative body to go to, and to pronounce at once what the instrument is—I speak from my own experience—it would be a great convenience, and I daresay you would find it so?—Of course I should; but in speaking for engineers in general, I say that there is not very much to be done in that way.

2125*. There was one point in your answer to Sir Courtenay Boyle, which was upon the question of standards of measurement, and I am quite prepared to agree with your evidence, but it is important that, although your standard yard may be correct, and so on, still in the case of a disputed measurement arising in certain delicate workmanship, it would be convenient, would it not, that you should be able to go to an authoritative body, and say, "What is this measurement?" There is no place where you can go to now, and speaking for myself, I feel sure that it would be a very great convenience if there were such a body?—I do not happen to have had any experience where that has occurred.

2126. But I have had it?—I have no doubt you have.

2127. In my experience it has frequently occurred, and when we had Sir William Anderson before us he freely admitted, speaking as the head of a Government department, that that was the case; it would be an immense advantage, and would do away with a great many troublesome disputes between the Government and their contractors if there were such a place where a disputed measurement could be authoritatively pronounced upon; at all events, you will go so far as to say that such a thing would be very useful?—Certainly.

2128. (*Mr. Roberts-Austen.*) I take it that you would consider that such a laboratory might well be occupied by the preservation of standard alloys, such alloys as would undergo change spontaneously, and such a laboratory might preserve standard specimens for reference?—Yes.

2129. And might even occupy itself with the determination of standard properties, if I might use such an expression?—Yes, you mean with the physico-chemical qualities.

2130. Mostly with the physical, as to why they undergo change; what are the most suitable alloys for certain definite purposes?—Yes.

2131. With reference to one of your answers, I do not think you are quite aware how much service has been rendered to the Alloys Committee by its chairman, Sir William Anderson; so far from the Committee having been left alone, he has given the most valuable help and direction, and has made many instruments at Woolwich for the Committee?—Of course, I am very glad to have that from you.

2132. (*Mr. Siemens.*) You have told us that the laboratory work would not be so very useful to engineers?—Except in the scientific aspect of matters, such as Mr. Roberts-Austen is engaged in.

2133. Surely such an institution could nominate Committees exactly as the Mechanical Engineers do, and they could carry out experiments in all sorts of ways; I mean that the systematic determination of physical constants and numerical data useful for scientific and industrial purposes could be carried out just in the same way as the Mechanical Engineers do it, only the Institution would be then the central point where everybody who wants things done knows he can go, and can get a Committee appointed to carry out investigations either in a laboratory or in a steamship?—I am sure that you will not get a Committee—I am speaking purely of engineers—quite so ready to work for a Department as they would be for their own body. I do not think it is the same thing.

2134. (*Dr. Thorpe.*) It would be treated rather as a Departmental question than a question which touches their own interest, you think?—Some of us have worked day and night over these things in connection with the Institution of Mechanical Engineers. The Marine Engines Committee, or the Riveted Joints Committee occupied many continuous days of work for some of us. I do not think that a public department, which is supposed always to be able to get what help it wants, would be able to get men to work in the same way for it. I think I should feel the difference myself.

2135. You were at one time at the head of an engineering laboratory?—Yes.

2136. And in the course of your experience in charge of that laboratory were not there many problems which must have occurred to you in which an institution of this kind might have been of service to you in the higher branches of scientific engineering?—There are many points which I should like to have investigated myself. I do not think I quite follow your question.

2137. For example, were you not in the course of your work, using a considerable number of instruments of which you required to know the quality?—Yes.

2138. And were not there amongst those instruments many which would be naturally standardised or verified at such an institution as we are contemplating?—One had always to calibrate them oneself.

2139. Would not you save a great amount of bother and trouble to yourself, and would not others in the same position be saved trouble if they could go to some authoritative body?—Speaking for laboratories, I should not like to say yes quite unhesitatingly. For purely laboratory work the man doing the work in the laboratory would wish to calibrate his own instruments, although a public body could do it for him.

2140. For example, you use thermometers, but you do not calibrate them?—We do not calibrate thermometers.

2141. If not thermometers, why not similar instruments?—Well, it may be prejudice.

2142. If you could get them equally well calibrated and equally well verified, why give yourself the trouble and your students the loss of valuable time in doing work of that description; what is the benefit to the student?—I do not think there is very much benefit to the student.

2143. Would not there be a great deal of saving both in time and energy?—In my own case I do not think there would be. The most difficult calibrations were mainly calibrations in connection with either large machines or apparatus which was put up in the laboratory itself, and which, therefore, was bound to be calibrated in the laboratory. I do not think there was anything, excepting always thermometers and indicator springs, that could have been sent outside to calibrate. Even electrical instruments, as

Sir Courtenay Boyle has pointed out, practically, must be calibrated in place. It does not follow that someone else on different work might not have been able to answer that question in other words, but that is how it is with myself.

2144. With reference to the question of copper tubes, I presume the behaviour of copper tubes is in many cases connected with the chemical nature of the copper?—I should imagine so.

2145. Now, the question of the investigation of the chemical nature of the copper is really a question of the investigation of the effect of minimal quantities of foreign substances?—Yes.

2146. And perhaps you are aware that the methods of determining these minimal quantities of foreign substances are not all that they ought to be?—I do not know that.

2147. Perhaps you are aware that we have no exact knowledge of the correlation of the physical and mechanical properties of the copper with its small quantities of foreign material?—That I am aware of.

2148. How do you conceive that the investigation of the correlation could be brought about?—That is undoubtedly laboratory work.

2149. In what class of institution ought it to be carried out?—It ought to be carried out by the people who make the copper.

2150. Why?—Because they are the people who are going to benefit most by it.

2151. But then in that case the purchaser of such copper would have to take the word of the person selling the copper as to the character of it?—Yes.

2152. Is that desirable?—Well, he tests it under the conditions under which he wishes to use it; that is, he tests it under pressure; that is, the probable condition.

2153. But even testing it under conditions under which it must be immediately used is not always satisfactory, because the question of time comes in?—Yes.

2154. How is the question of the behaviour of copper under the influence of time to be investigated; is it likely that the vendor of copper would take that trouble?—I think he should. I do not say that he does it, but if he is properly advised, and has his own chemist to work with him, or for him, he will make the tube of such alloy as he considers best, and in making a number of tubes he will test them from time to time, which is, after all, the only way in which the influence of time can be found.

2155. Is not it a fact that a very large number of tubes give way for which no valid reason can be assigned?—Yes. I believe that some give way without a valid reason, and many more give way with perfectly valid reasons.

2156. I am speaking so far as my own knowledge goes (and I have a certain amount of this work to do for the Board of Trade), that when we follow them up there are not infrequently cases where it seems impossible to give a valid reason?—Quite so.

2157. What organisation is to undertake an investigation of such a question as that?—That, of course, is the whole of the general question whether work should be done by a national and official institution, or by private individuals, by manufacturers, or by others. It is a very big question, and I do not know that I have any opinion to express upon it.

2158. Is not there an obvious inexpediency in having knowledge of that kind locked up in the possession of a particular manufacturer—is not it for the general interests of the community that knowledge should not be so locked up?—No, it is not so in the abstract.

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2159. How is the community to get the knowledge?—It wants to get the copper, it does not want the knowledge.

2160. But the knowledge is bound up with the copper?—Well, I suppose I am looking at it from a very practical point of view. I, as an engineer, want to get the results of the knowledge, no doubt, but I really want to get the copper.

2161. How are you to get the results of the knowledge?—I do not get them as it is. We do get the copper, and it is extremely good—we do not get all the secrets of the physical constitution of metals—as we know on the Steel Rails Committee—but I am not sure that we could get them any quicker if they were taken in hand in one institution than if you had half a dozen or twenty people working at them as now.

2162. Do you not think, speaking generally, that this is exactly the class of investigation that could be profitably undertaken by an institution of this kind?—Yes, if the institution were founded.

2163. (*Sir Courtenay Boyle.*) You have been good enough to refer to the testing of electrical instruments; are you able to answer me this question—whether in your opinion the calibration of electrical instruments other than the three standards are fairly well done at the Standards Department of the Board of Trade?—Yes, I have always had reason to think so. I have never heard anyone dispute it.

2164. So far as you know, both from your own experience and from industrial experience, Major Cardew does his work well?—Yes.

2165. (*Mr. Rücker.*) It seems to me that with respect to the second reference to us, you consider that the systematic determination of physical constants would be useful for industry?—Yes.

2166. I think a good deal of what you have said might be summed up in that phrase?—Yes.

2167. With regard to one other point, pyrometers, is it not likely in the future they will be used more largely?—I should be very glad to think so; it is quite possible. The reason that I paused in reply to Sir Andrew about that is that I did not want the Committee to think that I was speaking for any very large number of engineers who had these instruments, because, as a matter of fact, there are very few.

2168. (*Mr. Roberts-Austen.*) But if you contemplate ironworks' engineers then your answer would be different—take the temperature of the hot blast, for instance?—You know how roughly that is taken.

2169. Indeed, it is taken with very great accuracy now; there are to my knowledge at least forty pyrometers actually taking records of the temperature of the hot blast?—I have no doubt that you are perfectly right, but I did not know it. I was speaking of my own experience.

2170. Had you been referring not merely to engineers generally, but to ironworks' engineers, then your answer would have been somewhat different in relation to that pyrometer question?—Of course it would from what you have said, but, then. I have not personal knowledge in that direction.

Mr. Peter Samson, C.E., called; and Examined.

Mr. P. Samson, C.E.

2171. (*Mr. Rücker.*) You are engineer surveyor-in chief to the Board of Trade, I believe?—I am.

2172. In that capacity you have to use or to superintend the use of a great many instruments of one sort and another, have you not?—We have a considerable number of steam pressure gauges and a few micrometers, anemometers and pyrometers. These are the chief instruments we use.

2173. Are you satisfied with the way in which they are standardised, at present?—No.

2174. Do you think it desirable that there should be some further provision made for the standardising of such instruments?—I do.

2175. Are you aware of the outline of the general scheme for the provision of a National Physical Laboratory that was laid before the Prime Minister?—No.

2176. What would you yourself propose as the best means for meeting the want that you have just referred to?—I think a small body of very able men should be appointed to carry on research and other kindred work, collect and publish useful data, revise or determine physical constants and fix and keep standards.

2177. Could you specify some of the constants to which you refer?—We deal with large numbers of cylindrical flues and tubes, and at the present time we know very little of the laws which govern their resistance to collapse. So long as we stick to the usual dimensions we are pretty safe, but our knowledge of the subject is so imperfect that we cannot depart from those dimensions without incurring serious risk of getting into trouble. I also know from my own experience that some of the constants that have been determined would be all the better for being re-tested.

2178. (*Sir Courtenay Boyle.*) Such as?—The co-efficients of expansion of metals; I think these co-efficients might be gone into again with very great advantage.

2179. (*Mr. Rücker.*) Do you think that work of this sort requires to be done regularly and uniformly?—Yes; it wants to be done in a systematic way, and I think it would be economical to do it so. Large sums of money are being spent annually in making experiments, and the public get comparatively little out of them.

2180. Because?—Because the circumstances do not admit of the experiments being made in such a manner as

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to connect the several series together and much of the information so obtained is considered Departmental. The information that we get is no doubt embodied in our rules, and is useful in other ways, but the general public are deprived of the detail of those experiments which to them would be most useful and beneficial in every way.

2181. You have handed in, I think, a list of the various points on which you think determinations might be made?—Yes.

2182. Could you pick out one or two of them to which you would wish specially to refer?—I think we might deal with the question of pressure gauges first.

2183. What have you to say about them?—At the present time I don't think there are any wholly reliable means in this country for standardising pressure gauges, more especially those of the high pressure type. The principal makers certainly have mercury columns, but I do not feel certain as to the correctness of those columns; for instance, Messrs. Dewrance and Co., of Great Dover Street, who make a large number of pressure gauges, allow a height of mercury of 2·042 inches to represent a pressure of 1lb. per square inch, while others allow 2·035 inches. About six years ago a firm in Manchester wrote asking me to name a height of mercury that would represent a pressure of 1lb. per square inch, and I found, after making inquiries that there was no standard existing then, and I do not think the conditions have altered since. The mercury columns used in our large works are probably sufficiently accurate for practical purposes, but I think they cannot be regarded as standards.

2184. Do you think that there are many of these points which would be better studied in a laboratory than in a workshop?—Yes.

2185. (*Sir Courtenay Boyle.*) Will you mention to us the points on which you think experiments for determining constants might be useful?—I think there should be experiments for the determination of new constants and numerical data relative to a variety of subjects; and that there should be a checking over of old constants and formulæ, and the classifying and arranging them in such a manner as to make them readily available for use in every day practice. The subjects to which I refer include:—(*a*) The effect on materials produced by vibration or by variation or reversal of stress; (*b*) the determination of the natural elastic limits of metals; (*c*) expansion of metal or other substances; (*d*) galvanic action, especially in relation to its effect on propeller shafts; (*e*) influence of form on the strength of structures; (*f*) radiation of heat from steam pipes and similar objects; (*g*) co-efficients of friction in the bends and angles of water, air, and steam pipes; (*h*) the efficiency of cowl ventilators; (*j*) determination of the temperatures of the plates or tubes forming the heating surface of steam boilers; (*k*) the relative evaporative efficiency of furnaces, combustion chambers, and smoke tubes of marine boilers; (*l*) the laws which govern the strength of T and breeches pipes, so far as their ability to resist internal fluid pressure is concerned; (*m*) causes of the deterioration of brass or yellow metal; (*n*) the best form of safety valve for tar and oil stills; (*o*) the determination of the best material of which to make steam pipes, boiler tubes, and other structures exposed to considerable variation of temperature and vibration; (*p*) as to what alloy embodies in the greatest degree strength, ductility, and power of resisting oxidation; (*q*) as to the limit of strength to which it is practicable to make steel suitable for boiler-making purposes, and also for the construction of shafts and other working parts of marine engines; and (*r*) failures of copper pipes on board ship and the best means of preventing them.

2186. You have practically to advise the Board of Trade as to their rules for the surveying of ships?—Yes.

2187. Those rules in many instances almost amount to formulæ, do they not?—Yes, many of them include formulæ.

2188. In establishing those formulæ, the Board of Trade have to be guided by the advice of yourself and your colleagues?—Yes.

2189. You have a certain amount of laboratory qualifications, and laboratory experience, but you have not many laboratory opportunities, have you? Any experiments you conduct have to be conducted at the cost of the Department, and under special arrangement?—Yes, experiments are also made at the expense of manufacturers, and these are generally conducted at the works of those bearing the cost.

2190. With the sanction and with the co-operation of that maker?—Quite so. The maker pays for the experiments, and we arrange them and carry them out.

2191. Supposing you had a Government-supported, or a Government-encouraged, or, we will say, a Government-authorised body which could conduct these experiments, it would, in your practical administration, be of great service to you?—It would.

2192. Upon such points, for instance, as the behaviour of gauges and the expansion of metals, the causes of the deterioration of brass and yellow metal, and the behaviour of copper tubes?—Yes.

2193. Is it not the case that a very little while ago the behaviour of copper tubes came up before you for practical examination?—Yes.

2194. And special arrangements had to be made for testing the behaviour of those copper tubes?—Yes.

2195. If there existed, at Kew, say, a body capable of testing the behaviour of copper tubes, to whom those could be sent for an authoritative expression of opinion, it would have been eminently useful to the Department, would it not?—It would.

2196. You say you do not use many instruments; you do use some pyrometers, do you not?—We use pyrometers, and pressure gauges chiefly, but we also use micrometer gauges, steel measures and anemometers.

2197. And our friends here, at the Standards Department, your colleague, Mr. Chaney, for instance, have, no power of testing them?—None whatever. Messrs. Dewrance and Co. do our work so far as pressure gauges are concerned.

2198. Would it not be eminently desirable that those instruments should be calibrated by somebody in authority?—It would not, I think, be necessary to send pressure gauges to a Government Department to be adjusted, but I think it would be very desirable if firms like Messrs. Dewrance and Co., and other manufacturers of pressure gauges could get their standards standardised by somebody in authority.

2199. Do you think that would be of practical advantage, not only to the Department of the Board of Trade, but also to shipbuilders?—I think it would be a national advantage, because all pressure gauges throughout the country would then be adjusted to the one standard.

2200. (*Sir Andrew Noble.*) I notice that in your memorandum of evidence, among the subjects which you consider require attention, is the determining the best pitch and shape of the threads of screws, nuts, etc., most suitable for all the various purposes for which screwed threads and nuts are used. I have no doubt that if the Government insisted on it in their work we might hope in time to get it in the country; but have you any hope of getting a uniform system of screws?—Yes, I am in hopes of that. We have gone a long way towards it already by having the Whitworth and Sellars systems.

2201. What do you say as to the metric system of threads?—I think it would be desirable to adopt the metric system.

2201. I admit with you that it would be an immense advantage to the country, perhaps more to users than to makers, if there were a uniform standard screw fixed by the Board of Trade, or the great manufacturing establishments, that they would adhere to—of course, Whitworths do make according to a metric system as well as to their own old Whitworth standard; when you said you thought it would be desirable to adopt the metric system, were you thinking of the French metric system?—I was thinking more of the Whitworth system.

2203. Do you think it would be a great advantage if the Government would define a system of threads for all sizes?—I think it would be very desirable if they could do that, and also arrange with our colonies and foreign countries to adopt the same system. We might have to give and take a little so as to get one uniform system; but it would not, I think, be a difficult matter to arrange.

2204. (*Mr. Roberts-Austen.*) What kind of pyrometers do you employ?—They might be described as Wedgwood pyrometers. They are made by Bailey, of Manchester, and their indications depend on the difference in the linear expansion of two metal rods.

2205. Do you think that more ambitious appliances might be used if they were available?—Certainly.

2206. With reference to copper tubes, have you followed the work that has been done in the great Berlin Institution by Professor Martens on the commercial properties of copper?—No.

2207. Are you familiar with the work that has been done by the Screw Gauge Committee of the British Association—are they working on right lines, do you consider?—That I do not know.

M.. RICHARD WRIGHT-COLE, called; and Examined.

Mr. R. Wright-Cole.

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2208. (*Mr. Rücker.*) I believe you are a partner in the firm of Usher and Cole, watch manufacturers?—Yes.

2209. You have for many years past sent watches to be tested at Kew?—Yes.

2210. We want to know from you whether you have found the existence of such an institution useful to the trade?—Most decidedly.

2211. Could you tell us exactly in what ways?—You see it enables the retailer to give a guarantee with his watch. In many cases in London the name of the retailer is sufficient, but in others, and also in the country, the purchaser probably does not know that the man who is selling him the watch is a practical man, but if it is accompanied by a Kew certificate that is a guarantee of its quality.

2212. (*Sir Courtenay Boyle.*) What is the form of the certificate? What do they print upon the watch?—The certificate is a certificate issued with the watch.

2213. (*Mr. Rücker.*) And on the certificate the number of the watch and so on are given?—Yes; you are able to identify the watch by the number and description on the certificate.

2214. Do you find, in the watch making trade, that the public like the guarantee of an external and independent institution?—Yes.

2215. Do you think that the fact that there has been such a test has in any way led to the improvement of watches?—I think so, certainly.

2216. Do you think that the watchmakers have competed to attain the standard of accuracy set up by Kew?—Yes.

2217. It is the fact, is it not, that the number of watches which get very high marks at Kew is increasing annually?—Yes, it is.

2218. And that those interested in watches look anxiously every year for the appearance of what I may call the class list?—Yes, and I am happy to say we are at the top of it this year.

2219. Let me congratulate you?—Thank you. It is very beneficial in that way—there is no doubt about it. Greater attention has been paid to adjusting watches in consequence of the Kew test.

2220. In some cases, then, you would think it is desirable that such an institution should go a little before the public demand for a test of this sort?—Yes.

2221. There was no great public demand, I think, for it in the case of watches?—I think not.

2222. It originated, I believe I am right in saying, with Mr. Francis Galton; it was he who suggested it?—Yes, I think it was.

2223. But in spite of that you think that the trade have worked up to the standard which has been set to them?—Yes, certainly.

2224. And all your wants are fairly well met by the test at Kew at present, I suppose?—Yes, I think they are; I do not know that there is anything that could be very materially altered in it.

2225. As far as the suggestion for a National Physical Laboratory is concerned, as I understand, you think that in this particular the experiment has been tried and has been successful?—Yes. The only question is whether the National Physical Laboratory's Committee's certificate would not take a higher stand than the ordinary Kew Committee's certificate.

2226. Do you think there might be some advantage in having what you may call a State institution doing it, instead of a semi-private one?—I think so.

2227. Therefore, you would, on that ground, advocate the establishment of such a State institution?—I should.

2228. (*Sir Courtenay Boyle.*) Apart from the watch, as a whole, do you think it desirable to standardise or verify or calibrate—whatever the phrase is—the parts of the watch, say, for instance, the hair spring, or the main spring?—I do not think it is necessary.

2229. Are the hair springs and main springs made in England now?—Yes.

2230. They used to be bought abroad very largely?—Yes; but since the passing of the Merchandise Marks Act, they have been more largely made in England, especially the finer ones, the better ones.

2231. Then the Merchandise Marks Act has done some good to the trade?—No doubt it has to our trade.

2232. Now, as to the behaviour of steel; hair springs are nearly all made of steel, are they not?—Yes.

2233. Is it desirable to ascertain on authority the behaviour of steel in hair springs?—We should very much like it, I think.

2234. And so in regard to main springs?—Yes.

2235. You would like to have tested by some authority the quality of the steel used in main springs?—Yes, we should.

2236. (*Mr. Roberts-Austen.*) In regard to the uniformity of screw gauges; are the screws in watches made to a uniform pattern?—Yes, they are made to gauges.

2237. Therefore, there is no longer any necessity, as regards watches, for adopting measures for making the screws more uniform?—No, I do not think so.

2238. The uniformity is sufficient?—I should think so.

2239. (*Sir Andrew Noble.*) Do you mean that any one maker's screw gauge will fit into any others?—No, I do not think that is the case.

2240. (*Mr. Roberts-Austen.*) That is what I meant?—I do not think there is uniformity among the different makers, but I think that it would be highly desirable to have it.

2241. (*Sir Courtenay Boyle.*) You would wish to have uniformity of gauge amongst all the makers?—Yes.

2242. So that you could put a screw in somebody else's watch, and somebody else could put a screw in your watch?—Yes.

2243. (*Mr. Rücker.*) Have you any further points you wish to bring before us?—No, I do not think so.

Major PHILIP CARDEW, R.E., recalled; and further Examined.

Major P. Cardew, R.E.

2244. (*Mr. Rücker.*) We understand that you wish to supplement the evidence which you have already given us?—Yes. I rather wanted to correct some evidence that Mr. Glazebrook gave, in which I do not think he was exactly aware of the present position of our Laboratory. In the answers to Questions 797, 798, and 805, Mr. Glazebrook says he does not know why manufacturers do not apply to our laboratory for tests. I think I can explain that. As a matter of fact, Mr. Glazebrook's evidence was given on the 12th of November, and the official notice that our scale of fees had been approved by the Treasury is dated the 7th October. Before that approval we were unable to give any certificate, and of course the manufacturers were not satisfied to come to us, if they got nothing for their money—in fact, we could not take their money. Then at Questions 860, 861, and 862, he rather assumes that they prefer his certificate, but I do not think that is the case. At Question 862, he is asked, "May I gather—if I may put it so—that the trade value of a certificate issued under the auspices of the British Association Committee, is higher than that issued by the Board of Trade," and his reply is "I assume that to be the case, since they come to me for certificates." At that time we were not able to give certificates. Then as to whether we are able to take up the question as to whether the temperature co-efficients of certain important standard coils have changed appreciably in the last five or ten years. I have brought a curve that possibly might interest you, as I think you might like to see the work we do, but I do not know that it is necessary for it to go on the Minutes. This curve is a curve showing how the temperature co-efficient worked out for a certain standard coil, compared, of course, with another kept rigidly at one temperature. That shows that we can attain some degree of accuracy.

(*Mr. Rücker.*) I am not aware that there was an intention on the part of any body to make an attack on the work of the Board of Trade.

(*Sir Courtenay Boyle.*) I should venture on my own authority to say exactly what I am glad to hear you, sir, say, namely, that so far as I am aware there has been no attack made in the proceedings of this Committee upon the operations of the Electrical Standards Department of the Board of Trade, or upon the discharge of its duties. Major Cardew need be under no apprehension that the value of his work has been at all attacked before us.

(*Mr. Rücker.*) That is so.

(*Witness.*) I do not know whether it is necessary to go

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into the point raised in Question 302, and subsequent questions on Professor Ayrton's coils; that is a very undetermined thing as yet.

2245. (*Mr. Rücker.*) I think we shall be glad to hear what you wish to say upon it?—Mr. Glazebrook was wrong where he says in the answer to Question 808 that the Board of Trade certificates at present go only to one part in a thousand. For resistance coils we go to a very much higher accuracy than one part in a thousand, but for current and electric pressure we give certificates to one part in a thousand.

2246. I think he was referring to those latter certificates?—I suppose he was, but it rather looks as if he included resistance as he did not exclude resistance. For resistances, we contend that we can go to as high a degree of accuracy as is possible anywhere. We keep our resistance room always at a uniform temperature, and that in itself I think is a great advance.

2247. (*Sir Courtenay Boyle.*) Will you tell the Committee what you have done since the scale of fees has been approved by the Treasury—what amount of calibration or testing as distinguished from the absolute standardisation of instruments?—We have done twenty-four instruments since we began to take fees for them—mostly standard resistance coils, and certain current instruments also.

2248. (*Mr. Rücker.*) Counting each coil as a separate instrument?—Yes, except in the case of a box of coils; we have had one or two boxes of coils containing several coils, and each box would be counted as one. I do not think that at present people generally know that we are prepared to do such work, more particularly as regards current and electromotive force.

2249. (*Dr. Thorpe.*) What steps are taken to inform manufacturers that you are prepared to do this work?—I cannot say that we have pushed the thing very much. I have here a copy of the official notice which we published in the electrical papers.

2250. Do you think you have given it all proper publicity?—I should consider that proper publicity.

2251. (*Sir Courtenay Boyle.*) It was published once?—Yes, it was published once.

2252. (*Mr. Rücker.*) Have you got any further point that you wish to bring before us?—There was a question as regards the correctness of the silver equivalent which Mr. Glazebrook brought up in the answer to question 821. The matter was discussed internationally at Chicago on a proposal brought forward by Mr. Mascart, on November 6th, 1893—that was the date on which it was communicated officially. I have a letter here from Von Helmholtz, written to me, in which he makes the following statement:—"An important amendment in them"—that is in the conclusions of the Chicago Congress—"was proposed by Mr. Mascart, viz., to leave out altogether the electro-chemical equivalent of silver for defining the ampère, and to substitute a definition of the volt. I could not oppose this innovation, as the experiments continued here in the summer, principally by Dr. Kahle, seemed to show that in determining the silver equivalent, it is difficult to avoid difference of one one-thousandth, while in determining the electro-motive power with the Clark cell, it is comparatively easy and safe to obtain one two-thousandth." That shows that the matter was brought forward at the time, and that there was a slight difficulty and uncertainty. It was debated at Chicago, and the result was that they adhered to our figures for the silver equivalent.

2253. Mr. Glazebrook, in that question, is giving his personal opinion, is he not?—Yes; Mr. Glazebrook's opinion, apparently, is that the silver equivalent will be corrected. I have read the extract from that letter merely to show that I do not think it is likely that there will be any alteration internationally accepted.

2254. That is rather a scientific point of difference than any matter affecting the Board of Trade, is it not?—It is a legal question; we are in the position that we have a legal equivalent of silver now.

2255. (*Sir Courtenay Boyle.*) Surely what Mr. Glazebrook meant was that possibly there may be pressure put upon the Government to alter the legal determination?—Yes.

2256. He thinks there will be that pressure, and you think there will be not?—I think there will not. I think no pressure can be put unless it is put by foreign nations.

2257. (*Mr. Rücker.*) Is there any other point that you wish to bring before us?—There is nothing more, except that if it is thought useful, I could furnish the Committee with a list of the foreign scientists of distinction who have examined our methods.

Wednesday, 23rd March, 1898.

PRESENT:

Mr. A. W. RÜCKER, D.SC., F.R.S. (in the Chair).

Sir ANDREW NOBLE, K.C.B., F.R.S.
Sir JOHN WOLFE BARRY, K.C.B., F.R.S.
Mr. W. C. ROBERTS-AUSTEN, C.B., F.R.S.
Mr. ROBERT CHALMERS.

Mr. L. BLAIKIE, *Secretary.*

Sir Lowthian Bell, Bart., F.R.S
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Sir LOWTHIAN BELL, Bart., F.R.S., called; and Examined.

2258. (*Mr. Rücker.*) You are a Past President of the Iron and Steel Institute?—Yes.

2258*. I think you have seen the terms of reference?—Yes, but I am afraid I gathered rather an imperfect idea what your limits are to be.

2259. You have a general idea of the scheme, have you not?—I have.

2260. Have you formed any opinion as to the line in which the work should be most usefully carried out, or what limit should be put to it?—I would not like to say what the precise line of the limits should be, but there should be some limit to it, I am quite certain.

2261. Do you think that the limits are such that they could be usefully imposed by a committee of eminent scientific men and those interested in technology?—I think so; it would take longer time to consider that question than I have had an opportunity of devoting to it.

2262. You would consider such a body probably the best that such a matter could be entrusted to?—Yes, with a limit.

2263. Then, I presume, that limit would be that the Institution should not interfere with the work of investigation, either of the private investigator or of the technologist?—I do not know that they would, or would not. Of one of them I am quite certain that they could not.

2264. But, without such interference, do you think that there is a class of questions which could be usefully taken up by officials?—I think there is. On the lines of the Kew Observatory; if you could extend that to other branches of industry I think it would be useful.

2265. You are aware that we have helped several trades at Kew, including the watchmaking trade?—Yes.

2266. And you think that it is possible with further means that help could also be given to other branches of industry?—Well, I think that quite possible, but I would have a difficulty, perhaps, in seeing what at the present moment.

2267. I think I may take you through the terms of reference: With regard to the testing and verification of instruments for physical investigation, that is work which could be usefully done you think?—Yes.

2268. You are aware that a certain amount is already done by the Board of Trade in the Electrical and Standardising Department?—Yes.

2269. But without any clashing, do you think that there are other investigations outside the electrical which could be taken up?—I cannot impose any line between two bodies to prevent them coming in contact, if so

minded. Indeed, I am not sufficiently acquainted with the limits that the Board of Trade have imposed upon this to be able to answer that question.

2270. It has been suggested by the Superintendent of the Board of Trade Laboratory, Major Cardew, that it would be desirable that the Committee which managed the Physical Laboratory should be composed in such a manner that the two Institutions should be brought into direct contact—would that minimise any difficulties?—I could not give an opinion upon that.

2271. Then the next point is as to the systematic determination of physical constants: Do you think that that is work that could be well carried out by such an institution?—Yes, of course it would have this great advantage, that it would be in a similar position in public estimation to Kew. After Kew has passed a verdict upon any meteorological apparatus that is accepted at once as a trustworthy source of opinion, and altogether worthy of the confidence of those who are interested in the subject.

2272. You think that an extension of such work is desirable?—Yes.

2273. Do you think that it would be desirable that the management of such an Institution should be primarily in the hands of a body like the Royal Society, if it is clearly understood that technology should be largely represented on the Committee which manages the Laboratory?—To what extent, do you happen to know, has the Royal Society paid attention to questions of that kind?

2274. It is the body which appoints the Kew Committee, and in that sense has paid attention to questions of that kind. I should not consider the governing body of the Kew Institution altogether a technical committee—would you?—I should not.

2275. Only in part. You would like to see the technical element strengthened, I suppose?—Yes.

2276. Have you any suggestions to make as to any particular branches of enquiry that might be undertaken?—No, I have not yet had an opportunity of considering that question.

2277. But any such questions as the relation between the chemical constitution of iron and its magnetic properties or the physical properties of alloys—questions of that sort would be of the kind that you would suggest?—Yes. You are probably aware that there has been a good deal of attention paid of late years to the changes which take place in the resisting power of certain metals, the resistance to fracture for example, and, of course, the prominent one is that of rails. That is a question to which, during the last four or five years, I have paid a great deal of attention. No doubt there is a wide field there, and one in which the public personally is greatly interested.

2278. And there are some of those problems which could be taken up in a laboratory and investigated on what is called a small scale?—Well, the things which govern them might, but, of course, there is no other place than the railway of testing them finally, and the results are there so contradictory that one has a great difficulty in being able to draw any fixed rule for them.

2279. (*Sir Andrew Noble.*) I understand pretty clearly your view, but you would, would you not, esteem it an advantage if the purchasing public as well as the manufacturing public had the power of referring to a physical laboratory, such as we are considering, such questions as the standardising of steam indicators, steam gauges, pyrometers of various sorts, and electrical standards?—Yes.

2280. That would be an advantage to the country generally, would it not?—Yes.

2281. Then you are aware that the Board of Trade exercises a considerable supervision of certain standards now, but it would be a great advantage to them that they should have the power of consulting such a body as the governing body, which our Chairman has described, on various points of scientific importance?—Yes.

2282. And, also, that the Board of Trade should have the power of referring to them such things as secular changes in those instruments. There are in a good number of instruments various changes, especially in the electrical, that take a long time to develop; and it would be very important that they should have the power of consulting such a body on these points?—Well, I was not aware of what you were saying just now. Time alone, as I understand you, effects changes in the material of which the instruments are made, which considerably changes their properties; is that what you mean?

2283. Yes. I shall leave Sir John Wolfe Barry to ask you some questions on certain matters about which we have taken some evidence, such as secular changes in rails, either from fatigue or crystallization from long use, and so on?—Yes.

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2284. There are certain other questions, as, for example, the examination of photometric measurements, which now I have, from personal experience, a good deal of difficulty in having determined?—Undoubtedly that would be so.

2285. (*Sir John Wolfe Barry.*) I do not think I have very much to ask you. You have touched upon the question of rails, and I was only going to ask you if that was not a matter of the very highest importance, not only to the travelling public but to the trade of the country?—Of course it is.

2286. And should I be right in assuming that the value of experiments depends very largely upon their continuity, that is, that they should be carried on under the same conditions, and as far as possible under the same observers?—I think so.

2287. And that would be a kind of experiment which would be more naturally carried on in a National Laboratory than at any private laboratory?—I think that is very possible. It is a very wide field. The change you have spoken of takes place to a considerable extent in rails, and the question arises, What is that owing to? is it simply fatigue, or is there an alteration of the chemical constitution of the various parts of the rail which have undergone that change? Many years ago—20 years ago at least—I determined experimentally that the solid carbon in cast iron if exposed four or five weeks to a red heat and in contact with malleable iron that a portion of the carbon in the former passed over to the latter.

2288. (*Sir Andrew Noble.*) It is a question whether mere mechanical percussion may not effect the same change, that is to say, make the separation of carbon?—Yes.

2289. (*Sir John Wolfe Barry.*) And to that extent to alter the chemical constituents of a rail in use?—Well, Professor Roberts-Austen has had a great deal of experience, and I daresay he would be able to give you some very valuable information. I have some specimens here (producing the same and describing). These are magnified sections of parts of a rail, and the question is whether any change has taken place. Here is a field of intense whiteness, and there is a field of blackness. Is there any alteration of the composition of the white or the black? I do not know. But I have instructed our chemists to have an analysis made of that.

2290. Those matters that we have been alluding to are matters with which you have been particularly brought in contact, but there might be other subjects in other branches of industry which could equally well be demonstrated and experimented upon?—Yes, I cannot deny that.

2291. You spoke about the limit of such a Laboratory as we are speaking of; but perhaps you know that the limit of money is an important thing, and that is to be left in the hands of the Treasury?—It was because when I heard of it, and knowing the enormous amount of the field that you would have to cultivate, and the enormous number of ploughs you would have to set to work, that I despaired of your being able to do much good.

2292. Do you happen to be acquainted with the German Laboratory at Berlin?—No. I know generally 25 or 50 years ago in Germany they were far in advance of us in instruction in Technical Science.

2293. (*Mr. Roberts-Austen.*) The experiments that you have mentioned of your own with reference to the passage of carbon from one piece of iron to another have had very far-reaching results, but are they the kind of experiments that you would contemplate in such a Laboratory as is proposed?—That would depend rather upon the Directors of the Laboratory.

2294. But they are experiments of a kind that you think should be undertaken?—Yes, I think so.

2295. Then you think that the investigations of the Committee of which you and I are both members, the Steel Rails Committee of the Board of Trade, is work which might be entrusted to such a Laboratory?—No, because in an inquiry like that you require necessarily men of the stamp from which this institution will be chosen, but you require also engineers.

2296. I merely mean the experimental portion of the work, not the engineering?—Quite so.

2297. (*Sir Andrew Noble.*) If I might interpolate a question: The governing body would probably select a Sub-Committee of such men as were best qualified to conduct the experiments, would they not?—Yes, that would depend upon the good sense of the Institution,

2298. (*Mr. Roberts-Austen.*) Supposing such a Laboratory were established, do you think that it would receive

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much remunerative support in the way of work from outside—would the large manufacturers send work to be done there?—I doubt it.

2299. We have a good deal of evidence in favour of the view that they would?—Well, you see the one object a manufacturer has—there are exceptions, of course—is generally speaking to make money.

2300. (*Sir Andrew Noble.*) The prime object, is it not?—Well, the prime object. Then I do not know that it would answer the purpose of a private manufacturer to have his own views confided to the public at large.

2301. (*Sir John Wolfe Barry.*) But he would use the work done at this National Physical Laboratory as a starting point; it would save him, would it not, a great deal of preliminary investigation in many cases?—I cannot say.

2302. (*Mr. Roberts-Austen.*) All such questions as physical constants he would be glad to receive from such a Laboratory, would he not?—Yes. Until recently, as you know quite well, we have had a difficulty in ascertaining correctly or with any approach to correctness the temperatures of a very moderate degree—I mean of 400 or 500 Centigrade degrees. There was a piece of apparatus that was in constant use, but it never told you the temperature at the time that you wanted to know it; it was what they call the Siemens pyrometer, heating a cylinder of metal of a known specific heat, and ascertaining its effect upon a large volume of water. But now we have an apparatus at the Clarence Works, with which I am connected, where we ascertain the exact temperature.

2303. With parts of the work a quarter of a mile away?—Very nearly. They might quite well be 20 miles away.

2304. That is recorded by the pyrometer?—Not only have we that done, but there is a gentleman not far from me who has enabled us to have a record of the temperature of the air going into the blast furnace over the whole 24 hours.

2305. (*Sir Andrew Noble.*) I have something of the same sort I got from Paris, a recording pyrometer?——

2306. (*Mr. Rücker.*) You stated just now that at first you had some doubt as to whether a Laboratory would be useful, but I gather from the general tenour of your evidence that there is a fair prospect of its being useful?—Yes, in a restricted field.

2307. (*Sir Wolfe Barry.*) May I ask you whether you have not been experimenting almost all your life?—Yes, I daresay that is true.

Mr. R. A. Hadfield.

Mr. R. A. HADFIELD, called; and Examined.

2308. (*Mr. Rücker.*) You are a member of the Council of the Iron and Steel Institute?—Yes.

2309. And you are yourself a steel manufacturer?—Yes.

2310. You are aware, I think, of the general scope of the Physical Laboratory which is projected?—I have read a very interesting *resumé* of the objects of the Deputation on whose representation the Committee was appointed.

2311. Have you formed any opinion whether there are questions which could be with advantage submitted to such a body?—I think so; very many questions.

2312. Could you mention any within your own special knowledge?—It seems to me there are quite a number of points that might be taken up and great good done to the country at large—for example, the melting points of metals. I think a great work is to be done there in the accurate determination of the melting points of metals. It is a work which cannot very well be undertaken by private enterprise, as manufacturers have not the time nor the necessary apparatus required. Most of them have not a suitable laboratory in which such important and delicate experiments can be carried out, and I am sorry to say there are many to whom research work of this kind does not, on the face of it, appear to have any practical value. For example, I should suggest that the exact melting points of iron and the ordinary carbon steel alloys would prove of the greatest practical importance, commencing say, with pure iron, then steel with .10 per cent. carbon, the latter element gradually increasing until white iron containing 3½ to 4 per cent. of carbon was arrived at. I think if that information could be obtained, it would bring home to the mind of every-day users of iron and steel of various grades how different is the quality of the metal which we class under the generic term "steel."

2313. That is on a laboratory as distinguished from the manufacturing scale?—I think so, and that I think would necessarily lead to more systematic and accurate control of temperatures and of heating furnaces.

2314. You believe that to be a question of national importance so far as it benefits trade?—I do. I do not think that work of that kind would be undertaken by ordinary manufacturers. There are firms like Sir Andrew Noble's—if they set their specialists to work they could do it, but they have their own ordinary business going on each day, so that I think that one is rather apt to leave those things. At the present time—I may give an illustration—I have a very important series of nickel iron alloys containing varying percentages of nickel under examination from .10 per cent. to 50 per cent., but with the means at my own command or the time at my own disposal, I find it is not possible to obtain the data, and the only way I could get it done is to go to some scientific friend who was interested in such matters.

2315. And you would rather get the information for your own purposes?—No. I should add it to my own information in connection with the paper. I have written one or two special papers on alloy work, and I am only too pleased to do anything to make the information complete.

2316. But there are questions of this kind which it is desirable that the whole nation should have the whole benefit of?—Certainly.

2317. Do you think that one of the advantages of a national institution is that it would always publish its results, whereas the individual manufacturer might sometimes keep them himself if he made them in his own laboratory?—I presume he would, but not always. I know many of my friends who have contributed broadcast to the general benefit.

2318. (*Sir Andrew Noble.*) It would depend a great deal upon the cost would it not?—Certainly.

2319. (*Mr. Rücker.*) With regard to the melting points of metals, what have you to say?—I find many of the melting points of the chief metals are not known or not properly stated in the text-books. In my own case I have been unable to obtain information that would have saved me much costly experimenting and loss of time, if we had some central laboratory where one knew that experiments were going on and that information could be obtained.

2320. Is the determination of physical constants important from your point of view?—Very important, indeed. I have rather a striking illustration in some recent correspondence in the technical papers regarding the exact melting point of aluminium. This metal melts at a comparatively low point, but in this particular correspondence there have been about half-a-dozen opinions expressed. There can be only one real melting point, and it seems rather strange that one finds such divergence of opinion. If we had these melting points determined, it would lead to a much more rapid advance in metallurgical knowledge, and the same remark applies and still more so, as we have not any data, to such elements as chromium, tungsten and nickel. Nickel we have some information about, but I do not think that it is absolutely correct so far as I have had the opportunity of noting; and even pure iron itself; I very much doubt if we have the exact melting point of pure iron to-day.

2321. There are a number of such melting points that ought to be determined by some independent authority, you think?—Exactly; as you say, by an independent authority. In some work I did upon alloys of manganese and iron, not only could I not obtain a specimen of the metallic manganese, but the melting point of the purest specimen of manganese that I could get varied many hundred degrees from the temperature stated in the text book. A few years ago, a most inaccurate statement appeared in the technical press, and unfortunately this information has now got into the text-books. That was that the addition of .05 per cent. of aluminium added to molten and carbonless iron lowered the melting point several hundred degrees. That is absolutely incorrect.

(*Mr. Roberts-Austen.*) Certainly.

(*Witness.*) If we had an independent laboratory it would not have been possible for such a statement regarding the incorrect temperature to creep in, and to younger men that are growing up the only source of information they have is the text-book. The same remark applies to the determination of heat resisting properties of refractories, including fireclays, of which we know so little. Lord Kelvin has spoken very decisively upon the same point. All metallurgical operations are largely dependent upon good refractories, and yet we know very little about them, nor is it possible any one manufacturer could take up and accurately determine such a subject as this.

I think our knowledge at the present time generally on the question of temperatures is very meagre. I think a very valuable work could be done by a National Physical Laboratory in bringing home to all those interested as to what a temperature of 1,000 degrees centigrade means. As metallurgy advances we are becoming still more dependent every year upon the accurate determination and correct understanding of the various temperatures. Whilst the ordinary every-day knowledge is wonderfully accurate for present requirements, each year we metallurgists are required to deal with steel and other metals of more complex nature, the most of them exceedingly sensitive to the slightest variations from that particular and correct temperature at which they should be treated.

2322. (*Mr. Rücker.*) Then you regard the very accurate determination of high temperatures as an important thing from a metallurgical point of view?—Yes, I do. It was recently brought home to me very prominently by one of the large steel manufacturers in Sheffield, who makes armour plates, and who finds the use of the pyrometer of great service. If there had not been a practical pyrometer available, they doubted very much whether they could get the results now being reached. As regards the question of pyrometers, we are all very much indebted to Professor Roberts-Austen for what he has done, but he would admit that the pyrometers at present available are rather delicate instruments. I do not know whether it is possible to simplify them. I had the pleasure of seeing one made by Mr. Crompton, which seemed to me a very simple apparatus, one based upon electrical resistance.

2323. I may, perhaps, tell you that experiments are being carried on at Paris under the auspices of the Kew Committee, of comparing pyrometers with the gas thermometer; do you think that such experiments are needed?—I do. Then, as regards the properties of metals I find in my own work that it is almost impossible to get, even with many common metals, the correct data regarding not only the melting points, but their various physical characteristics and also electrical properties. In fact, specimens of many of the pure metals seem entirely wanting. I remember some three or four years ago I was in the Cavendish Laboratory at Cambridge, and was much interested in seeing a number of specimens of so-called pure metals arranged most carefully and precisely. I begged a few grammes of one of the various metals shown to me as representing manganese. On analysing it at our laboratory, I found that it contained a very considerable percentage of carbon. If there had been a laboratory such as you are proposing I think that such an error as that would have been avoided. Naturally, any student examining such a specimen must get his ideas from that one placed before him. The metal manganese with carbon would vary in its properties as much as pure iron does as compared with .4 carbon steel. Another case, which I am glad does not concern our own country, was this: I was recently in Germany, and there I met a very interesting and clever manufacturing chemist. Some magnificent specimens of the metal chromium made by an ingenious and novel process were put before me. I asked for my own information what were the physical properties of the metal itself. I had the usual reply—that chromium was a very hard metal. Owing to the behaviour of my own alloys of iron and chromium in which carbon was practically absent, I had every reason to doubt the statement made to me. Fortunately some specimens of chromium containing 98 per cent. of the metal were available, and they were tested with an ordinary file. To most of those present, the result was a surprise, as it was found that the chromium metal could be easily filed, and could not, therefore, be described as a hard metal in the sense ordinarily understood. Therefore, it seems to me that there is not only room for research in producing and examining the various metals of practical and scientific interest, but also of ascertaining their physical properties.

2324. From which it would appear that for the determination of physical properties the data are not all worked out?—Not at all. I am only speaking as a practical man, and not as a scientist. There may be better specimens of the metal available that I am aware of. Then another important field for research, which a manufacturer cannot very well touch, and which I do not think has been referred to in your notes, would be some better and more accurate method of determining the hardness of the metals themselves, and also of their various alloys. At the present time hardness in a metal may mean a material which is brittle, or which resists abrasion, or which possesses glass-scratching hardness. Our knowledge in this respect is most empirical.

2325. (*Sir Andrew Noble.*) You never tested hardness by trying to get an impression with a hard point?—We have made some experiments, but it is most difficult to carry them out on a practical scale. You get so many discordant results, and then a metal may be very hard in the lathe or a drilling machine, and yet I have seen specimens which could be touched with a file most readily. These are most contradictory qualities, because we have not had them carefully examined, I suppose. Geologists seem to have worked out salvation for their own particular line, but their knowledge seems of little advantage as applied to the metals. A hard metal may, notwithstanding this apparent quality, wear away quickly, whilst a much softer metal may wear well, that is, prove more durable when resisting abrasive action.

2326. From what—because there are various modes of making a metal wear. I am thinking, for instance, of the passage of heat, the action of gases, and so on?—Quite so; that is quite a different class.

2327. That is why I asked the question. You mean purely mechanical?—Yes, purely mechanical—I should call that more corrosive action.

2328. Or erosive?—But it comes more near to some chemical action; at least, I should think so.

2329. (*Mr. Rücker.*) You are speaking of mechanical abrasion?—Certainly. I think most puzzling anomalies are to be met with in every-day practice, and yet it cannot be doubted that with accurate means of determining hardness, many of our difficulties would be cleared away, or much reduced. When one thinks that the world generally is engaged in trying to rub itself away, man can only keep his place by trying to counteract that tendency as regards the use of metals in the mechanical arts. There is also a great want of a National Laboratory for determining the special mechanical properties of metals, the effect of fatigue of all kinds, a matter upon which we know but little at the present time, but which is occasionally brought home to us in a very unpleasant manner by breakdowns and accidents. I suppose all the Committee will have seen Kirkcaldy's very interesting museum of specimens. It is a very small museum, but I was at that time very much impressed with his magnificent specimens; that is some years ago—before the use of testing had been brought home to us. But ... you could accumulate a Laboratory of that kind or a museum in connection with the Laboratory, it would prove most interesting and valuable.

2330. With regard to the testing and verification of instruments, what have you to say?—I cannot very well offer a very decisive opinion upon that, but I think it is very necessary.

2331. As to the question of fatigue in metals, have you paid any attention to it?—Not very much, except in the ordinary way of testing.

2332. Do you know of any demand on the part of manufacturers for tests of the kind that you describe?—Yes, I think there is; it has become more so.

2333. Do they ever go to the Reichsanstalt for such tests?—Not mechanical tests; but I was rather annoyed a short time ago to find that some friends of mine in this country had a letter from an intending user who said that the use of a certain kind of steel could not be considered unless a certificate from the Reichsanstalt could be produced. I held it to be rather a remarkable proof of the value of the work done by that Institution; but it was the cause of no little chagrin to myself that, before business could be done in this country, a German mark of approval had to be obtained.

2334. There are one or two points I wish to ask you about. In the first place, as you yourself said, the field you have described is a very large one. Do you think that a properly constituted body would have any very grave difficulty in selecting from among the various problems suggested to them?—I should not imagine so.

2335. You do not think that the Institution would be over-burdened by the large number of problems suggested to it?—No, I think not. You cannot exactly map out any very special line; at any rate, there is room for making a commencement and doing very valuable work for the country at large.

2336. Are you acquainted at all with the Kew Observatory?—No.

2337. Do you think that the technical world would be satisfied with a mixed governing body, composed partly of scientific men and partly of technical men, appointed possibly by the Royal Society?—Yes.

2338. You think there would be no objection to that scheme?—No, I think that we are getting much more open-minded on that subject. I find manufacturers recognise the assistance given by scientific men much more than they used to do. In my own City of Sheffield we find that

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as regards University College, in which is combined both the Firth College and also the Technical School, many manufacturers are now much more open to reason regarding its practical use. Ten years ago there was a very different opinion.

2339. You think there is a growing demand for scientific help amongst the manufacturers?—I do.

2340. (*Sir Andrew Noble.*) I entirely agree with most of what you say, but you mentioned an uncertainty about the melting point of metals and alloys?—Yes.

2341. I suppose that the variations that you have referred to are probably due either to the metal not being in all cases perfectly pure, or to a variation in the case of alloys—of the composition of the alloy?—Possibly.

2342. For example, it is well known to you that in bronze there is frequently a very considerable variation in the composition between the top of an ingot and the bottom of it, and that might easily affect the temperature?—Certainly.

2343. Then you referred to some points touching specific heat. You would agree that some of the physical constants that would be of great importance to the manufacturers would be the changes of the specific heat with temperature, as regards gases, fluids, and solids?—Certainly.

2344. I ask you whether, especially as to the two former, our knowledge is not very defective?—Yes, it is.

2345. And that could hardly be carried on except in such a laboratory as we are contemplating?—Certainly not.

2346. Then the only other point I need trouble you about is your allusion to pyrometers and to the variation in results, with comparatively small variations in temperature. You would regard it as of great imporance that users of pyrometers should have the power of going to such a physical laboratory to have the accuracy of their pyrometers tested from time to time?—Yes.

2347. And that also, I might say, would be probably a self-supporting arrangement?—Yes. I presume that some of the Committee would have the intention of making charges.

2348. Clearly, I am afraid the Treasury would put a very sharp limit upon the Committee if they did not. In fact, what I said about pyrometers applies to an immense number of other instruments in constant use by engineers?—Yes.

2349. (*Mr. Roberts-Austen.*) Few manufacturers, if any, have been so ready in publishing the results as Mr. Hadfield's firm, but may we hope that other manufacturers would follow your example, do you think?—I think if you consult the papers of various Institutions you will find more disposition in that direction. I have done it myself. I have often done it selfishly—but frequently find it of great value to exchange opinions. One may get certain ideas, they may not be correct, and if you have them criticised it is an advantage.

2350. You think the more widely knowledge is diffused the better for the manufacturing community?—Yes.

2351. The only point is: would the work be remunerative? Would the manufacturers be alive to the advantages of the pyrometer, for instance, or an instrument of a similar kind, and would they be glad to consult the laboratory about it, so as to prove remunerative?—Yes, I think that is the case in Germany. In talking to friends over there, I find that they consult the Reichsanstalt.

2352. In the case of your own works, among the varied questions that arise, there are many questions that you would consult such an Institution on and pay a reasonable fee to them?—I think so, on many of the points that I have put forward.

2353. You would pay a reasonable fee for the knowledge that you wanted?—Certainly. I should like to make a few remarks about that. In my own case I have a large number of scientific friends who are only too anxious to assist me; but I can well understand that there are many other manufacturers, who have not come in contact so much with scientists, and they do not know where to get these results.

2354. That is an accident of your living in a great centre of activity, is it not?—I think so, and what I find useful, others would find the same, I think.

2355. Would you define somewhat more exactly what you mean by the importance of knowing temperature accurately, say, on either side of 900 degrees?—Well, I think that some alloys might be benefited by certain temperature above 900, and others might not be benefited.

2356. There would be critical points in such alloys in which a range of a few degrees only would make all the difference in the world on their physical properties?—I mentioned about 900 degrees, but if we consider about 700 or 800 it would be still more apparent.

LIST OF THE APPENDICES.

A.—Staff of the Office of Standard Weights and Measures; Staff of the Electrical Standardizing Laboratory; and Table of Fees for Testing Electrical Instruments. (*Put in by Sir Courtenay Boyle.*)

B.—Papers put in by Mr. H. J. Chaney :—

1. List of Physical Standards of Weights and Measures.
2. Metrological Investigations undertaken at the Bureau International.
3. List of Imperial and Metric Standards verified by the Board of Trade during 1895-96.
4. Descriptive list of instruments other than Imperial or Metric Standards tested by the Standards Department.
5. Applications received from manufacturers and others for assistance, which the Department has declined.
6. Physical constants and numerical data referred to at the Standards Office, with respect to which further investigations appear to be desirable.
7. Investigations undertaken by the Phys.-technische Reichsanstalt which appear (*inter alia*) to affect the work of the Department.
8. List of Verification Fees (Standards Office).

C.—Kew Observatory : Charges for Verification. (*Put in by Dr. C. Chree.*)

D.—Report on the behaviour of certain alloys used for the wire of resistance coils. (*Put in by Mr. R. K. Gray.*)

E.—List of Subjects suggested for Research to the Council of the Institution of Mechanical Engineers. (*Put in by Mr. W. H. Maw.*)

Appendix A.

APPENDIX A.

STAFF OF THE OFFICE OF STANDARD WEIGHTS AND MEASURES, 7, Old Palace Yard.

	Salary.
Superintendent of Weights and Measures	600*l.*
First Class Assistant Clerk	390*l.* to 400*l.*
Second Class Assistant Clerk	350*l.*
Second Division Clerk	179*l.* to 250*l.* or 350*l.*
Mechanic and Office Keeper	107*l.* 10*s.* to 120*l.* (residence, &c.)
Assistant Mechanic and Messenger	85*l.*

TEMPORARY STAFF, SUBJECT TO 1 MONTH'S NOTICE.

Temporary or additional Mechanic	130*l.*, *i.e.*, 50*s.* a week.
,, ,, ,,	104*l.*, *i.e.*, 40*s.* a week.

SUBORDINATE TEMPORARY CLERICAL ASSISTANCE.

2 Copyists at 10*d.* per hour	about 100*l.* each.

ELECTRICAL STANDARDIZING LABORATORY.

The testing of electrical instruments has only recently been commenced; the notice to the Press of the readiness of the Department to undertake the duties was not published till the 12th October, 1897.

The Testing Staff consists of: —	Salary.
The Electrician	300*l.*
The Assistant Electrician*	100*l.*

*Temporary.

NOTE.—The testing of instruments forms but a small part of the duties of these gentlemen.

Up to October 28th, 1897:—

The number of applications for tests was 13.
Amount of Fees received — 6*l.* 9*s.*

ELECTRICAL STANDARIZING LABORATORY.

TABLE of Fees for Examination or Testing of Electrical Instruments for the Measurement of Resistance, Current, or Electrical Pressure.

	£	s.	d.
1. For an instrument intended to be used as a sub-standard and submitted for special examination and testing	3	0	0
If required to be kept under observation for a period longer than one month; for each additional month or part of a month	1	0	0
2. For ordinary direct-reading instruments; for testing at three points:...			
Voltmeter for continuous pressure only:—			
Not exceeding 200 volts	0	5	0
Exceeding 200 and not exceeding 500 volts	0	6	0
Exceeding 500 and not exceeding 2,000 volts	0	7	6
Voltmeter for alternating pressure only:—			
Exceeding 20 and not exceeding 2,000 volts	0	7	6
Exceeding 2,000 and not exceeding 10,000 volts	0	10	0
Extra fee if tests are to be made at one stated frequency of alternation	0	2	0
Voltmeter for both continuous and alternating pressures, or for alternating at two frequencies:—			
Exceeding 20 and not exceeding 2,000 volts	0	10	0
Ammeter for continuous current only:—			
Not exceeding 200 amperes	0	5	0
Exceeding 200 and not exceeding 500 amperes	0	7	6
Exceeding 500 and not exceeding 1,000 amperes	0	10	0
Exceeding 1,000 and not exceeding 2,500 amperes	0	15	0
Ammeter for alternating current only:—			
Not exceeding 500 amperes	0	7	6
Extra fee if tests are to be made at one stated frequency of alternation	0	2	0
Ammeter for both continuous and alternating currents:—			
Not exceeding 500 amperes	0	10	0
Watt-meter—continuous current—for testing at three points:—			
Not exceeding 200 volts or 200 amperes	0	12	0
Exceeding these limits up to 2,000 volts or 2,500 amperes	0	15	0
Watt-meter—alternating current—for testing at three points:—			
Not exceeding 10,000 volts or 1,000 amperes	1	0	0
For each point tested beyond three points in any direct-reading instrument an addition of 20 per cent. will be made to the amount of fee.			
In the case of any direct-reading instrument if arranged to record, and if the accuracy of such record is required to be verified:—			
Extra fee for every record verified	0	2	6
3. For instruments reading by an adjustment to zero, an increase of 50 per cent. on the fees for similar direct-reading instruments will be charged.			
4. For determining the constants of integrating meters* at three rates within their range of measurement:—			
Quantity meter, continuous current only:—			
Up to a maximum rate of 25 amperes	0	10	0
Up to a maximum rate exceeding 25 and not exceeding 100 amperes	0	15	0
Up to a maximum rate exceeding 100 and not exceeding 500 amperes	1	0	0
Up to a maximum rate exceeding 500 and not exceeding 2,000 amperes	1	10	0
Quantity meter, alternating current:—			
Up to a maximum rate of 25 amperes:—			
If to be tested at one frequency of alternation	0	10	0
If to be tested at two frequencies, or at one frequency of alternation, and with continuous current	0	15	0
Up to a maximum rate exceeding 25 and not exceeding 100 amperes:—			
If to be tested at one frequency	0	15	0
If to be tested at two frequencies, or at one frequency of alternation, and with continuous current	1	2	6

* These instruments will only be accepted for testing if intended to be used as sub-standards or for scientific purposes.

	£	s.	d.
Up to a maximum rate exceeding 100 and not exceeding 500 amperes:—			
If to be tested at one frequency - -	1	0	0
If to be tested at two frequencies, or at one frequency of alternation, and with continuous current - - -	1	10	0
Energy meter, continuous current only:—			
Up to a maximum rate of 10,000 watts	0	15	0
Up to a maximum rate exceeding 10,000 and not exceeding 50,000 watts - - - - - - - -	1	0	0
Up to a maximum rate exceeding 50,000 and not exceeding 200,000 watts -	1	10	0
Energy meter, alternating current *:—			
Up to a maximum rate of 20,000 watts:—			
If to be tested at one frequency - -	1	0	0
If to be tested at two frequencies, or at one frequency of alternation, and with continuous current - - -	1	10	0
Up to a maximum rate exceeding 20,000 watts, and not exceeding 100,000 watts:—			
If to be tested at one frequency- -	1	10	0
If to be tested at two frequencies, or at one frequency of alternation, and with continuous current - - -	2	5	0
For each rate tested beyond three rates in any meter an addition of 20 per cent. will be made to the amount of fee.			

	£	s.	d.
5. For testing resistances and standard cells:—			
For a resistance coil of not less than 1 ohm resistance to an accuracy of 0·01 per cent. - - - - - - - - -	0	5	0
For a resistance coil of resistance between 1 ohm and $\frac{1}{1000}$ ohm to an accuracy of 0·1 per cent. - - - - - -	0	5	0
For a box of resistance coils with Wheatstone bridge, Post Office or dial pattern, to an accuracy of 0·1 per cent., per coil tested - - - - - -	0	0	6
With a minimum fee of - - - - -	0	2	6
For a coil of standard form to highest accuracy obtainable at one temperature	0	10	0
For determining the E.M.F. of a Clark's standard cell at one temperature -	0	5	0
For testing resistances and standard cells at two different and determined temperatures the fee to be charged will be twice that specified above, with an additional charge of 5s. for each instrument.			

In the case of all the above-mentioned tests, except tests of standard instruments, integrating meters, and resistances, the fees charged will be reduced by one-third if from six to twelve similar instruments are submitted at the same time, and by one-half if the number exceeds twelve.

Appendix A.

APPENDIX B.

Appendix B.

1. List of physical standards of weights and measures in use in the United Kingdom, being parts and multiples of the standards representing the fundamental units of measurement.

(A.)

IMPERIAL STANDARDS BASED ON THE YARD AND POUND.

MEASURES OF LENGTH:
Parts and multiples of the yard, from a measure of 100 feet to a measure of 0·01 inch.

MEASURES OF CAPACITY:
Parts and multiples of the gallon, from a measure of 32 gallons to one of a quarter gill.

APOTHECARIES' MEASURES:
40 fluid ounces, to half a fluid ounce.
16 fluid drachms, to half a fluid drachm.
60 minims to 1 minim.

AVOIRDUPOIS WEIGHTS:
Parts and multiples of the avoirdupois pound, from a weight of 100 lb. to ½ dram.

PENNYWEIGHTS:
20 pennyweights to 1 pennyweight.

TROY WEIGHT:
Decimal troy ounce bullion weights:
Parts and multiples of the troy ounce, from 500 ounces to 0·001 ounce.

APOTHECARIES' WEIGHT:
Parts and multiples of the troy ounce, from 10 ounces to half a grain.

COIN WEIGHTS:
Weights for determining the weight of gold and silver coins.

DECIMAL GRAIN WEIGHTS:
From 7,000 grains (1 lb. avoirdupois) to 0·01 grain.

(B.)

METRIC STANDARDS BASED ON THE METRE AND KILOGRAM.

MEASURES OF LENGTH:
Metre sub-divided into decimetres, centimetres, and millimetres.

MEASURES OF CAPACITY:
Double decalitre to one centilitre.

WEIGHTS:
20 Kilograms to 1 milligram.

2.—METROLOGICAL Investigations undertaken at the International Bureau of Weights and Measures at Paris.

Form and Material of International and National Standard Measures.

Mode of construction of these Prototypes.

Periodical re-comparisons of National Prototypes.

Variation of Gravity with Latitude and Altitude.

Tension of Vapour of Water.

Weight of Litre of Air.

Density of Water, and Mass of Cubic Centimetre of Water.

Thermometrical Researches, and Standardising of Thermometers.

Density and Expansion of Mercury.

Densities and Expansions of Metals and Alloys used in the construction of Standards.

Comparison of Imperial Standard Pound with the Kilogram, and of the Imperial Standard Yard with the Metre.

Length of Metre and Yard in terms of Wave Lengths of Light.

Standardising and Comparison of Geodetic Measuring Bars.

* No greater alternating current than 500 amperes can be measured.

Appendix B

3.—List of Standards of the Imperial and Metric Systems verified by the Board of Trade during 1895-6.

PRIMARY STANDARDS.

Inland Revenue Department, Ottawa.
500 grams to 0·1 gram.
India (Government of).
Steel gauge—0·451 inch.
Iridio platinum, weight of 100 grains.
Perak (Government of).
10 feet and 50 feet standard measures.
Russian Government.
2½ Sachen and Imperial equivalents (Platinum iridium).
Siam (Government of),
100 feet,
40 metres.
Western Australia (Government of),
56 lb. to ½ dram.

SECONDARY STANDARDS.

Admiralty:
56 lb. to 4 drams,
2 sets each, 2 gallons to ½ gill.

Bank of England:
(*a*) Troy Bullion weights:—193 weights.
(*b*) 1 set of grain weights, 600 to ·01 grain.

War Department:
56 lb. to ½ dram,
Gallon to ½ gill.

Royal Mint:
2 sets Troy Bullion weights, 500 oz. to ·001 oz.
1 set Standard Coin Weights.

Straits Settlement (Government):
Standard pikul, kati, chee and hoon, weights.

Lancashire Fishery Board:
Gauges for Shell-fish for use in verifying other gauges.

LOCAL STANDARDS.

Measures of Length, 59.
Measures of Capacity, 536.
Weights, 3,048.

MANUFACTURERS' STANDARDS.

7 (*a*) Measures of Length.
15 (*b*) Measures of Capacity.
144 (*c*) Weights.
(*a*) For 3 manufacturers.
(*b*) ,, 5 ,,
(*c*) ,, 10 ,,

4.—Descriptive List of Instruments, being other than Imperial or Metric Standards, *tested by* the Standards Department.

Gas:—
4 Cubic Foot Bottles,
45 Experimental Meters,
1 Gas-Holder,
40 Gas Meter Governors,
2 Gas Meters.

Gauges:—
3 Calliper Gauges,
10 Dry Measure Gauges,
2 Gun-ring Gauges,
5 Shell-fish Gauges,
43 Wire Gauges.

Geometry:—
100 Instruments used for the examination of Inspectors.

Gravities:—
104 Petroleum Apparatus.
21 Specific Gravity Bottles.

Measures, Linear:—
131 Boxwood Rules.
502 Measuring Tapes.
9 Verniers.
344 Measures for other purposes.

Measures of Capacity:—
2 Foreign and Colonial Native Measures of Capacity.
12 Measures for other purposes.

Metric:—
1 Metric Linear Measure,
1 Metric Measure of Capacity,
24 Metric Weights.

Thermometry:—
152 Thermometers.

Water:—
41 Water Pressure Gauges.

Weighing—Instruments:—
817 Balances and Scale-beams for Local Authorities,
43 Weighing Instruments for other purposes.

Weights:—
13 Assay Weights,
261 Grain Weights,
127 Weights for Foreign and Colonial Authorities.

5.—Applications received from Manufacturers and others for assistance which the Department has declined.

Testing of steam pressure gauges.

Testing of water-meters.

Verification of instruments used in testing the strength of materials.

Verification of standards of light.

Testing of gas-burners (excepting where so required in any private Act, *e.g.*, the Commercial Gas Act, 1875; the South Metropolitan Gas Light and Coke Company's Act, 1876; and the Gas Light and Coke Company's Act, 1876).

Verification of large weighing-machines.

Verification of hydrometers.

Verification of thermometers, other than for use in the measurement of gas and the testing of petroleum, or thermometers used with linear standards.

6.—Physical Constants and Numerical Data.

In the following investigations, physical constants and numerical data are referred to at the Standards Office, with respect to which further investigations appear to be desirable:—

Mass of unit volume of air.

Mass of unit volume of water.

Densities, co-efficients of expansion, and elastic moduli of materials suitable for the construction of standards.

Numerical data as to the density and expansion of alcohol and mercury.

Analyses of materials employed for standards purposes, with a view to their exact reproduction whenever necessary.

7.—Investigations undertaken by the German Reichsanstalt, or Standarising Institution, at Berlin.

The following investigations undertaken by the German Reichsanstalt appear *(inter alia)* to affect the work of the Standards Department of the Board of Trade:—

Determination of the expansion of water.

Investigation of the densities of gases.

Examination of the variation of the elasticity of metals at different temperatures.

Similar examination with respect to glass.

Studies in the measurement of low temperatures.

Studies in the conduction of heat.

Study of the laws of radiation of opaque substances.

Experiments in bolometric measurements.

Researches in the definition of the radiations of the platinum unit of light.

Experiments on Talbot's Law in Photometry.

Researches on the volatile products of steel and dilute acids.

Study of the solubility of salts in water.

Testing of thermometers.

Testing of petroleum apparatus.

Testing of manometers and barometers.

Testing of standards of light.

8.—BOARD OF TRADE.

List of Verification Fees.

	£	s.	d.
(1.) Primary Standards:—			
For Indian, Colonial, or Foreign Governments, each	20	0	0
(2.) Secondary Standards:—			
For Indian, Colonial, or Foreign Governments, each set of weights or measures	2	10	0
Each separate weight or measure	0	10	0
(3.) Scientific Standards:—			
Weights, each	0	5	0
Measures of capacity, each	0	10	0
Measures of length	1	0	0
Measures of volume	1	0	0
(4.) Standards for other purposes:—			
Weights, each	0	1	0
Measures of capacity, each	0	2	6
Measures of length, each	0	2	6
Measures of volume, each	0	5	0

No fees are payable on the verification of standards for the use of Local Authorities in the United Kingdom, or for the use of Departments of H.M.'s Government.

(5.) Weights and Measures, weighing or measuring instruments for ordinary use	0	5	0
(6.) Testing weights, etc., in disputed cases, each	0	5	0
(7.) Examination of Inspectors:—			
On examination	1	0	0

	£	s.	d.
(8.) Miscellaneous:—			
Examination of public and mural standards submitted by local authorities, or of instrumental equipment of inspector's office	5	5	0
Petroleum testing apparatus	0	5	0
Standard weights for coins:—			
For each weight from 5*l.* to a farthing, a fee of 6*d.* is payable on its verification.			
For each complete dozen of sovereign weights under twelve dozen, or a gross	0	5	0
For each complete gross of sovereign weights	2	10	0
And the same for half sovereign weights.			
Photometer scale, or measure of length	1	0	0
Photometer burner	0	10	0
Photometer, other measures	0	10	0
Photometer, weights and weighing instruments	0	5	0
For examination of scale beams, each	0	5	0
For examination of vernier and comparator, each	0	2	0
For examination of grain weights, each set	0	5	0
For examination of "hopper and strike," each	0	5	0
For examination of verifying gauge for measures of capacity, each	0	2	6
For examination of glass pipettes or burettes, each set	0	5	0

Standards Department, Board of Trade,
1st January, 1892.

Appendix B.

APPENDIX C.

Appendix C.

KEW OBSERVATORY.

Charges for Verification.

The following charges for verification and rating include certificates with tables of corrections, copies of which are retained at the Observatory:—

Barometers and Aneroids.

	s.	d.
Standard, with *either* inch or metre scales and attached thermometer	0	6	0
Standard, with *both*	0	7	6
Marine or portable, with attached thermometer	0	10	6
Mountain or siphon, ,, ,, ,,	0	7	6
Aneroids, ordinary (26in. to 31in.)	0	5	0
,, ,, with table of temperature corrections	0	10	0
Aneroids (15in. to 30in.)	0	7	6
,, ,, with fixed altitude scale	0	8	6
With table of temperature corrections (additional)	0	5	0

Thermometers.

	£	s.	d.
Standards, 32 deg. to 212 deg. Faht., compared at every 10 deg.	0	5	0
Ordinary meteorological, 12 deg. to 92 deg. Faht., compared at every 10 deg.	0	1	6
Ordinary maximum, 22 deg. to 92 deg. Faht., compared at every 10 deg.	0	1	6
Ordinary minimum, 12 deg. to 72 deg. Faht., compared at every 10 deg.	0	1	6
Six's, with both scales, compared at every 10 deg.	0	2	0
Dimension, with both scales (maximum and minimum), compared at every 10 deg.	0	2	0
Inverting, 32 deg. to 92 deg., compared at every 10 deg.	0	2	0
*Immisch's Avitreous, 32 deg. to 110 deg. Faht., compared at every 10 deg.	0	1	6
*Immisch's, for clinical use, 90 deg. to 110 deg. Faht., compared at every 5 deg.	0	1	0
(* If less than 6 sent, double fees charged.)			
Solar radiation, unmounted, 32 deg. to 150 deg. Faht., compared at every 10 deg.	0	3	6
Deep sea sounding, tested under hydraulic pressure, compared at every 10 deg.	0	5	0
Clinical, 95 deg. to 110 deg., compared at every 5 deg.	0	1	0
Mountain or "boiling point." 180 deg. to 212 deg. Faht., compared at evry 5 deg.	0	2	6
Solar radiation (in vacuo)	0	5	0
Instruments of exceptional ranges or construction—*Special Rates.*			

Standard Thermometers.

Made and supplied under certain conditions:—

	£	s.	d.
Range extending to 220 deg. Faht., or 105 deg. Cent.	1	10	0
Range extending to 400 deg. Faht., or 205 deg. Cent.	2	0	0
Range above 400 deg. Faht., or 205 deg. Cent.	2	10	0

Hydrometers.

	£	s.	d.
Ordinary hydrometers, lactometers, and urinometers (1,000 deg. to 1,040 deg. sp. gr.), compared every 10 deg.	0	1	0
Saccharometers for light fluids (1,000 deg. to 1,040 deg. sp. gr.), compared every 10 deg.	0	1	0
Saccharometers for heavy fluids (1,000 deg. to 1,140 deg. sp. gr.), compared every 20 deg.	0	2	6

Appendix C.

	£	s.	d.
Salinometers (temperature, 200 deg. Faht.)	0	2	6
Salinometers (temperature, 60 deg. Faht.)	0	1	0
Sikes's hydrometers (0 deg. to 100 deg.), compared every 10 deg.	0	5	0
Sikes's hydrometers (60 deg. to 90 deg.), compared every 10 deg.	0	1	0
Specific gravity bottles	0	3	6

Twaddle's and other hydrometers—*Special Rates.*

SEXTANTS, THEODOLITES AND COMPASSES.

Sextants, Class A, tested every 15 deg.	0	6	0
Sextants, Class B, tested every 30 deg.	0	3	6
Theodolites examined at every 30 deg. of arc, index error of compass found, &c.	0	7	6
Compasses—standard	0	7	6
Compasses—steering	0	5	0
Compasses—liquid	0	2	6
Compasses—prismatic azimuth, examined every 30 deg. of arc.	0	2	6
Artificial horizons, levels and mirrors, examined and marked	0	2	6

TELESCOPES AND BINOCULARS.

Marine telescopes and superior binoculars, examined and hall-marked	0	2	9
Pocket telescopes and opera glasses, examined and hall-marked	0	2	0
Photographic lenses, Class A.	0	12	6
Photographic lenses, Class B.	0	7	6

MAGNETIC INSTRUMENTS.

	£	s.	d.
Unifilars	5	5	0
Dip circles, 2 needles	1	1	0
Dip circles, 4 needles	2	2	0

Magnetographs—*Special Rates.*

MISCELLANEOUS.

Rain gauges	0	2	6
Glass measures for the above	0	1	0
Small Robinson cup anemometers, with dials, directly compared with standard	0	7	6
Air meters run on whirling machine up to velocities of 2,500 feet per minute	0	7	6
Sunshine Recorders	0	6	0
Recording thermograph or barograph	1	1	0

WATCHES AND CHRONOMETERS.

Watches rated under Class A conditions	1	1	0
Watches rated under Class B conditions	0	10	6
Marine chronometers, Class A.	2	2	0
Marine chronometers, Class B.	1	1	0

NOTE.—With watches, thermometers and other instruments where the certificate implies the attainment of a certain standard, rejected instruments are charged half fees.

Appendix D.

APPENDIX D.

REPORT ON THE BEHAVIOUR OF CERTAIN ALLOYS USED FOR THE WIRES OF RESISTANCE COILS.

Authors' Club,
3, Whitehall Court, S.W.,
1st December, 1897.

Dear Sir,—In answer to your request of yesterday I give you some matters of fact that ought to weigh in favour of the National Laboratory.

During the past six years, in supervising the manufacture of apparatus for various systems of duplex telegraphy for submarine lines, I have collected evidence as to the behaviour of alloys, such as are used for the wire of resistance coils. Many thousands of bobbins came under my notice, from latitudes as widely different as: Valparaiso, Calcutta, Texas, Panama and Rio de Janeiro. Last Friday I gave an account of these bobbins at a meeting of the Physical Society. Briefly, the result of observation on several thousands of bobbins proves that platinoid and German silver fail, for our purpose. Platinoid is a cheap material, closely allied to German silver. These alloys become rotten, the wires fall to pieces, the electrical circuits break, and the whole telegraphic system is impaired until new bobbins can be obtained from England. Matters became so serious this year that I adopted platinum-silver for all coils; this is an alloy of silver and platinum; it is very costly; it is made in England. I have no definite proof that it will stand against the conditions of the tropics; we have no means of obtaining data as to the effect of time and of environment upon such material.

In the meantime, samples are being sent to us from Germany of cheaper alloys, of high specific resistance, and very low temperature-coefficients. The Reichsanstalt has made careful investigations with regard to Manganin wire, showing how to solder it, how not to solder it, how to protect it, and how to wind it, and they declare that it is proof against failure under all ordinary conditions. Manganin is being introduced from Germany, and British manufacturers are already beginning to adopt it; they have faith in the work that has been done upon it by the Reichsanstalt. Thus, in a year or two, if no steps are taken to prevent it, British manufacturers will buy their resistance coil wire from the same foreign market that supplies them with sheathing-wire. There is no institution in England to combat the difficulty.

Four years ago a similar question arose with regard to paraffin-wax for electrical condensers. When our wants became known, samples of every kind of paraffin-wax were submitted to us by almost every post, from Germany. I arranged a test for them, such as might be carried out easily at a National Laboratory. The result was that British wax of certain make was proved to be far better than anything from the other side of the Channel. If this variety were marked by some National Institution, and classed as of high electrical quality, with notes as to the best conditions for using it, British manufacturers would adopt it in preference to any foreign wax.

Another matter that has come under my own notice is the measurement of the electrical resistance of certain dielectrics. From certain tests, I have proved that accuracy depends very largely upon perfect contact between the dielectric and the testing-electrodes. Contact should be made with mercury; otherwise, what may really be a very faulty dielectric may seem to have extremely high resistance. Methods for computing dielectric resistance for commercial purposes in America, Germany and England are for the most part ambiguous, the results are nearly always too high. If English buyers purchase on ambiguous foreign tests, the result must be failure. We require a National Laboratory for the proper testing of dielectric material. For instance, the other day some india-rubber gloves were submitted to me. They were for use by workmen on very dangerous alternating-current circuits. They were specified to withstand a certain number of volts. I was asked to test them to that voltage with an induction-coil spark; I did so, and no fault was discovered, although the voltage was far above the specified value. I objected to this test on the ground that there was no account taken of the electric current through the gloves, and I suggested that they should be tested for this. I had them tested at the much lower voltage, but more powerful current from an alternating dynamo, with water inside and outside the gloves. They immediately broke down.

Now there are very few makers of india-rubber gloves who have at their command a powerful alternating current dynamo and transformer. And it is scarcely to be expected that, even if they had such apparatus, they could afford to keep on their staff an electrician of sufficient knowledge and experience to be trusted with the work of guarding and using the deadly weapons of such a testing system. Thus, from the very humanitarian view of safety to workmen and others, a National Laboratory is evidently to be desired.

Yours very truly,
ROLLO APPLEYARD.

Robert Gray, Esq.,
106, Cannon Street,
London, E.C.

APPENDIX E.

INSTITUTION OF MECHANICAL ENGINEERS.

Experimental Research.

Subjects Suggested for Research.

Corrosion and deterioration of iron bridges.
Axle testing.
Iron and Steel, constitution and tempering.
Intermittent friction at high speeds.
Friction on cutting-tools for stone.
Deterioration of copper fire-boxes and brass tubes.
Crystallisation and contraction in iron castings.
Efficiency of long struts.
Torsional strength of hollow shafts.
Loss of heat from steam pipes as affected by flanges stop valves, etc.
Train resistances.

With reference to the above list, Mr. Maw writes :—"I find that no complete record has been kept of all subjects suggested, but I believe the annexed list includes the chief subjects which have been brought before the Institution and not yet dealt with."

INDEX OF EVIDENCE.

ALLOYS.

The systematic investigation of, would probably yield results of great technical value, (*Lodge*) 890-7; (*Kelvin*) 1169-71; (*Samuelson*) 1503-5; (*Hadfield*) 2312-4.

The systematic investigation of, cannot be satisfactorily carried out by private enterprize (*Samuelson*) 1506; (*Hadfield*) 2312, 2314.

Investigation needed as to:—

Most suitable alloys for mechanical purposes as for boiler-tubes, (*Samuelson*) 1505-7: (*Maw*) 1741-4; (*Kennedy*) 2114*-20; (*Samson*) 2185; for resistance coils, (*Obach*) 1944.

Cause of failure of alloys, (*Kelvin*) 1164; (*Anderson*) 1651, 1668*; (*Samson*) 2185; (*Preece*) 2065-75.

Changes induced in alloys by time or vibration, (*Kelvin*) 1117; (*Samuelson*) 1502-5; (*Hopkinson*) 1534; (*Kennedy*) 2128.

Hardness of metals, (*Hadfield*) 2324-9.

Melting points of alloys, (*Preece*) 2034; (*Hadfield*) 2312-21.

See also *Manganin. Crank axles. Rails.*

ALLOYS RESEARCH COMMITTEE

(of the Institution of Mechanical Engineers).

Work of, of great importance; might have been entrusted to a national physical laboratory, if established, (Anderson) 1664-8; (Maw) 1722-5, 1853-9; (Ayrton) 2016; (Preece) 2070-2.

See also *Research Committees.*

AMPERE.

Re-determination of, needed, (*Glazebrook*) 821-2; (*Lodge*) 870; (*Foster*) 946.

Question as to the possible alteration of the legal value of the electro-chemical equivalent of silver (*Glazebrook*) 821; (*Cardew*) 2252-6.

ANDERSON, SIR WILLIAM.

Nominated by the Institution of Civil Engineers.

For evidence see pp. 64-7. Analysis:—

Desirable that a central impartial authority be established to standardize instruments, test certain materials, and to decide in case of disputes as to measurements, 1610-22, 1636-8, 1661. Desirable that the way in which certain gauges should be used be authoritatively fixed, 1654-60. It would be of great service to the Department of the Woolwich Arsenal if an institution were established in which investigations and tests could be carried out on behalf of, and at the cost of, the Department, 1639-53, 1661, 1668*-71, 1674-6, 1700-1. Considers that manufacturers would wish to have investigations made at such a laboratory at their own cost, the results being freely published; but in certain cases it might be necessary and desirable to delay publication for a limited time, 1671-2, 1684-99. Describes the work of the Research Committees of the Institution of Mechanical Engineers, 1664. Much of the work of the Alloys Research Committee might have been carried out at a laboratory such as is contemplated, 1665-6. The management of such a laboratory, if established, should be entrusted to the Royal Society; desirable that the Committee of Management should not necessarily consist exclusively of Fellows of the Society, and should contain representatives of technology, 1628-32. The director should be a man of high scientific position; the salary attached to that post should be about £2,000 per annum, 1677-81.

ANEMOMETERS.

Need of improved means of testing, (*Scott*) 1209; (*Samson*) 2172-4.

AYRTON, PROFESSOR W. E.

Nominated by the British Association

For evidence see pp. 77-81. Analysis:—

Desirable that further facilities be provided for the public testing of instruments, particularly of pressure gauges, 1982-4; speed indicators, 1985; spectacles, 1986-8; electrical condensers, 1991; standards of self and mutual induction, 1992; search lights, 2013-4. A public institution should be established to construct new standards and to carry on investigation in connection with standards, 1989, 1995. It is not part of the duty of the Board of Trade Electrical Laboratory to construct new standards, 1995. Accurate standards of electrical capacity much needed, 1991. There is considerable vagueness with reference to the standards of light, a fifty-candle power standard should be constructed, 1989-90. Investigation should be carried out as to the conductivity of copper, 1996. The determination of the temperature coefficients of resistance coils is of great scientific importance, 1998-9. Considers it of great importance that facilities should be provided for testing the conductivity of samples of copper wire and the insulation resistance of samples of covered wire, 1996, 2001-2. Experience as to wire supplied by manufacturers in connection with electric light work, 2001. The re-determination of the specific heat of super-heated steam is urgently needed, 2003. Investigations of great importance to engineers could be carried out in a physical laboratory, 2003-4. The results of technical researches frequently cannot be protected by patents; desirable that such information should be obtained at the public expense, and published for the general benefit, 2005. Considers that the Royal Society and the more important technical societies should be represented on the governing body of a national physical laboratory, if established, 2009. Such governing body should have the duty of advising the Board of Trade, when required, and of examining the standards at the Board of Trade laboratories from time to time, 2010. An account should be published of all the work done in such a laboratory, if established, 2006. The site of Kew Observatory is suitable for a physical laboratory, 2007. A very small amount of electrical disturbance would make the site useless for many experiments, 2008.

BELL, SIR LOWTHIAN

Nominated by the Iron and Steel Institute.

For evidence see pp. 90-2. Analysis:—

Desirable that further facilities be provided for the public testing of instruments and the systematic determination of physical constants, 2267, 2271-2, 2279, 2284. Experiments on many matters of great technical importance could be carried out in a laboratory such as is contemplated, 2277-8, 2285-97. Some limit must be placed on the scope of the work to be attempted, 2260-4, 2291. Considers that such a laboratory, if established, would not receive much remunerative support in the way of work sent in by manufacturers, 2298-300. Technology should be largely represented on the governing body, 2273-5. This body should have the duty of advising the Board of Trade, when necessary, on matters of scientific importance, 2281.

BIDWELL, MR. SHELFORD.

Nominated by the Physical Society.

For evidence see pp. 27-9 Analysis:—

The progress of scientific research is hindered by the want of knowledge as to the values of important physical constants, 712. The determination of such data frequently cannot be carried out by the individual worker, 714, 768. It should be undertaken by officials working under adequate scientific control, 715-7. The subjects to be investigated should be selected by the director or the committee of direction, 730-65. The testing of instruments would be of great assistance to scientific workers, 770, 785-9. The cost of verifying instruments might be largely met by charging moderate fees for testing, 774. The site of a physical laboratory should be free from electrical and mechanical disturbances; the site of Kew Observatory suitable 726-8.

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BINOCULARS.
Tested at Kew Observatory, (*Chree*) 480.

BOARD OF TRADE
Statement of the position of, as bearing upon the question of the relation to the State to standards so far as those standards have to do with weights and measures, (*Boyle*) 47-59.
See also *Electrical Standardizing Laboratory. Marine Department. Standards Department.*

BOILERS, WATER TUBE.
Experiments on, should be conducted by men with technical knowledge, (*Kennedy*) 2112-4*.
Material for, importance of investigation of, (*Samuelson*) 1505-7; (*Maw*) 1741-3 (*Kennedy*) 2112-20; (*Samson*) 2185.

BOYLE, SIR COURTENAY. (A member of the Committee).
For evidence see pp. 5-7. Analysis :—
States the position of the Board of Trade as bearing upon the question of the relation of the State to standards, in so far as those standards have to do with weights and measures, 47-59. The officers of the Standards Department are trained in the department, 60-1. There is no Advisory Committee at the Standards Department, or Electrical Department; opinion as to the desirability of setting up such a committee, 62-5.

BRASS.
Investigation needed as to the cause of deterioration of, (*Kelvin*) 1164; (*Anderson*) 1651, 1668*; (*Samson*) 2185.
Testing of, by the cooling curve method cannot be done at the Woolwich Arsenal on account of the mechanical disturbances, (*Anderson*) 1624.

BRITISH ASSOCIATION.
Connection of Kew Observatory with, (*Galton, D.*) 1; (*Galton, F.*) 323.
Presidential addresses on, and report of committee on, the question of the desirability of establishing a national physical laboratory, (*Galton, D.*) 1-2.
See also *Electrical Standards Committee.*

BUREAU INTERNATIONAL DES POIDS ET MESURES.
Board of Trade associated with, (*Chaney*) 81-3, 207.
Appointed for the purpose of research and not only for standardizing, (*Chaney*) 205-6.
No important step taken at the Standard Office as to methods of construction or verification of primary or secondary standards without reference to, (*Chaney*) 82.
For list of investigations undertaken at, bearing upon the work of the Standards Office, *see* Appendix B2.
A gas thermometer is adopted as the ultimate standard of temperature, (*Chree*) 465.
Mercury-in-glass thermometers verified at the Bureau used at the Standards Office, (*Chaney*) 116.
Have adopted a French glass, *verre dur*, for standard mercury-in-glass thermometers, (*Chree*) 546.

CABLES, ELECTRIC.
Importance of accurate knowledge of the capacity of, (*Ayrton*) 1991.
Facilities should be provided for the impartial testing of the insulation resistance of, (*Swinburne*) 1409; (*Ayrton*) 2001-2.

CAPACITY, ELECTRICAL.
Need of a standard of, (*Glazebrook*) 799; (*Kelvin*) 1124; (*Ayrton*) 1991.
Commercial standards of, frequently a half per cent. wrong, (*Ayrton*) 1991.
The Board of Trade do not propose, as at present advised, to establish a standard, (*Cardew*) 285-9.

CARDEW, MAJOR PHILIP.
Electrical Adviser to the Board of Trade.
For evidence see pp. 12-15, 89-90. Analysis :—
Describes the origin of the Electrical Standardising Laboratory, 247-9, 309. Standards of current, electrical pressure, and resistance have been established, 241. Mercury resistance standard is not used, 259-61. Work of the Department does not include investigation as to the absolute values of the electrical units, 251-2, 269-70. As at present advised are not prepared to establish standards for other electrical quantities, 285-9. If the standards were at variance between themselves appeal would be made for assistance to the recognised scientific bodies, 251-3, 314-5. Personally would hail assistance from an advisory body, 298. Under present circumstances an advisory body could have no formal status, 310-3. Considers the site of the laboratory suitable, 244, 274-5, 290-5. Instruments are tested for manufacturers and the public, 241, 2244-51. Degree of accuracy, 2245-6. Method of testing small resistances, 266-8. Appliances are adequate for the work undertaken, 273. The staff must be increased if a large number of instruments are sent in for testing, 281-2. Considers that the testing of instruments for manufacturers is more conveniently carried out in London than elsewhere, 273-80. Question as to the correctness of the legal electro-chemical equivalent of silver, 2252-6.

CHANEY, MR. H. J.
Superintendent of Weights and Measures.
For evidence see pp.7-12. Analysis :—
The primary duty of the Standards Department is the preservation of standards, their construction and restoration and the verification of copies of those standards with the primary standards, 74-9. The powers and facilities of the Department are adequate for this class of work, 80. The Department is in constant communication with the International Bureau at Paris, 81-2. Staff of the Department, 87. Expenditure, 87-91. Testing of instruments other than Imperial and Metric Standards, 92-113, (for list of instruments *see* App. B.4). In some cases the instrument is tested to the highest degree of accuracy attainable, 110-1. The Board of Trade have power to set up a standard Fahrenheit thermometer; no legal standard at present established; the position in regard to thermometry, legally speaking, is not altogether satisfactory, 115-28. Describes the method of verifying thermometers for use with the Abel flashing point instrument, 129-34. Cannot undertake the testing of thermometers for scientific purposes except for their own use on account of the smallness of the staff, 138-142. Applications received from manufacturers and others for testing which have been refused, 114 (*see also* Appendix, B.5). There is a considerable demand for the testing of steam pressure gauges, 165-6; standards of light, 166-7; water meters, 166; hydrometers, 224-5; apparatus for determining the mechanical properties of metals —viz., the moduli of elasticity, 193-4. Would decline to verify a planimeter and similarly in the case of many other instruments, 188-92. A certificate is issued with all instruments verified, 169-71. Cannot undertake investigations in connection with standards; have no legal obligation to initiate new data or new numerical expressions, 159-61 195-200. Many of the data in actual use may be wrong, 199 (for list of data in respect to which new determinations appear to be desirable *see* Appendix B.6). Uncertainty might be produced as to any new standard weight, 143, 146-150. Desirable to reproduce the means afforded by the German Reichsanstalt as to the analysis of materials and the work of scientific research, 144-5. (For statement of investigations carried out at the Reichsanstalt of importance to the Department, *see* Appendix, B.7.) Fees not charged on statutory work at the Standards Office, 176. Fees charged for commercial testing might perhaps with advantage be lowered, 176-83. List of Verification Fees, Appendix B.8.

CHEMICAL INVESTIGATIONS.
A subsidiary chemical laboratory should be attached to a national physical laboratory, if established, to test the purity of materials employed, and to study the methods of producing pure materials, (*Obach*) 1903-7, 1949-53.
Desirable to reproduce in England the means afforded by the Reichsanstalt as to the chemical analysis of the materials employed in the construction of standards, (*Chaney*) 143-56.

NOTE.—Major Cardew gave evidence on October 20th, November 5th, and March 9th.

CHEMICAL INVESTIGATIONS—*continued.*

At the Reichsanstalt is undertaken a considerable amount of chemical investigation not strictly required for the physical work, (*Obach*) 1952

The preparation of pure metals cannot we be conducted by private persons, (*Bidwell*) 767-8

CHREE, DR. CHARLES.

(Superintendent of the Kew Observatory)

For Evidence see pp. 19-27. Analysis :—

Describes the work of the Kew Observatory as an observatory, 435-6; work done for the Meteorological Council, 439-42; testing of magnetic instruments, 443-6; of clinical thermometers, 449-51; meteorological thermometers, 452-4, 457-8, 583-7; hydrometers, 475-8; sextants, 479; binoculars, 480; photographic lenses, 483-4, 550, 557; commissions executed, 485-7; instruction of observers, 488-90; replies to inquiries on scientific matters, 491-2; construction of standard thermometers, 569; special tests conducted for manufacturers, 539-40. Kew Stamp not a registered mark, 599-612.

Income of the Observatory, 493-501. Relation to the Royal Society and to the Government, 493-4, 505-6. Extension of buildings is paid for out of the ordinary revenue, 506. Sum available too small for the necessary extension of the work, 515. Chief wants of the Observatory are the means of a close scientific study of thermometry, and of extending the testing arrangements, 550. The Kew standard thermometer is not satisfactory; scale of, should be compared with that of the gas thermometer, 465-71, 699. The comparison of the scale of the platinum thermometer with that of the gas thermometer is being made at the Bureau International on behalf of the Kew Observatory, 507-13. The depression of the zero in thermometers of English glass is very large, 623. The magnetic work at Kew is of great importance; the present chamber in which self-recording instruments are placed not wholly satisfactory, 670-5. Cannot undertake the higher class of thermometric work at the Observatory on account of the smallness of the scientific staff and of want of apparatus, 459-62. Applications received for tests which could not be undertaken, 519-38.

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COPPER.

Investigation needed as to the influence of impurities on the properties of, (*Ayrton*) 1996; (*Kennedy*) 2144-61.

Need of impartial test of samples of, (*Anderson*) 1651, 1661; (*Ayrton*) 1996.

COPPER STEAM PIPES.

Experiments on, must be made by persons having practical knowledge of the matter, (*Kennedy*) 2114-5.

Need of investigation as to the cause of failure of, (*Samson*) 2185, 2192-3.

The present arrangements for the testing of, sufficient (*Maw*) 1834-50; (*Kennedy*) 2111-2.

CRANK AXLES.

esirable to ascertain the cause of failure of; practice of railway companies in relation to failure of; the subject is investigated by the railway companies within the limits of their own requirements; scientific experiments on crank axles would be of little practical value, (*Maw*) 1796-1810, 1824-33.

CROMPTON MR. ROOKES E.

(Nominated by the Institution of Electrical Engineers.)

For evidence see pp. 50-4. Analysis :—

English engineers are hampered by the want of facilities for standardising instruments, 1282. Describes some researches carried out in connection with the business of electrical engineering, 1283-97. Such investigations should be undertaken by a national institution and might be largely self-supporting, 1298, 1310-2, 1318-23, 1347-8. Considers that it would be impossible to carry out very accurate work at the Electrical Standardising Laboratory of the Board of Trade, 1352-3. Considers that the governing body of a national physical laboratory, if established, should act

CROMPTON, MR ROOKES E.—*continued.*

as a visiting committee to the Board of Trade Laboratory, and that the latter should have an official right to consult the body aforesaid on matters of difficulty, 1360-3. Considers that the management of such a laboratory might be entrusted to a committee nominated by the Royal Society, provided there were a sufficient number of commercial men on the committee, 1301-2. In certain cases it might be advisable that a private report be given on an incomplete investigation carried out in such a laboratory for a private person, 1364-78.

CRUSHER GAUGES.

Need of improved means of testing the copper (*Anderson*) 1661, 1669-71.

CRYSTALLIZATION OF STEEL.

See *Elastic Fatigue, Crank Axles, Rails.*

ELASTIC FATIGUE.

Need of investigation of; cannot well be undertaken by private enterprise, (*Foster*) 969-70; (*Thompson*) 1076-83; (*Kelvin*) 1114-7; (*Samuelson*) 1502-5; (*Hopkinson*) 1534, 1580, 1597; (*Hadfield*) 2329.

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ELECTRICAL INSTRUMENTS, STANDARDISING OF.

Cannot be undertaken at Kew Observatory, (*Scott*, 1211.

There is no provision for the testing of many classes of electrical instruments at the Board of Trade Laboratory, (*Thompson*) 1009, 1074; (*Kelvin*) 1090-2; (*Preece*) 2026-7.

An institution should be established to examine and check new methods of, and devices for, making comparisons before they are introduced into the actual standardising laboratory, (*Glazebrook*) 829-39.

See also *Electrical Standardising Laboratory, Electrical Standards Committee, Resistance Coils, Capacity, Self Induction, Mutual Induction.*

ELECTRICAL STANDARDISING LABORATORY, BOARD OF TRADE.

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Origin of, and scope of work of, 239-52.

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As at present advised it is not proposed to establish a standard of capacity at, (*Cardew*) 285-9.

Personally would hail assistance from an advisory body, (*Cardew*) 298.

An advisory body could have no formal status under the existing conditions, (*Cardew*) 310-2.

Considers that certain very accurate work cannot be undertaken in the laboratory as at present equipped, (*Glazebrook*) 802, 857; (*Crompton*) 1308-9. 1352-3; (*Ayrton*) 1999-2000.

Important not to interfere with the existing work of (*Hopkinson*) 1538.

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ELECTRICAL STANDARDS

See *Ampere, Capacity, Mutual Induction, Ohm, Self Induction, Volt.*

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ELECTRICAL STANDARDS COMMITTEE, BRITISH ASSOCIATION.

Work carried out at the Cavendish Laboratory in connection with, (*Glazebrook*) 793.

Board of Trade standard ohm depends on the standard coils of the British Association, 794-5.

Testing of resistance coils for; a considerable fee charged for testing in order to limit the work; the actual testing of the coils might be undertaken at the Board of Trade Laboratory, 796-802, 826-8.

ELECTROLYTES.

Determination of the conductivities of saline solutions needed for technical purposes, (*Obach*) 1898; (*Preece*) 2034.

ELLIS, MR. W.

Nominated by the Royal Meteorological Society.

For evidence, see p. 49-50. Analysis:—

Further facilities should be provided for the standardizing of instruments, 1261-3. The testing of magnetic and meteorological instruments at Kew Observatory has been of great value, 1263-8. The existing means for testing thermometers for meteorological purposes at Kew are sufficient, 1269. The need of an institution such as is contemplated has frequently been felt, particularly in connection with the construction of standards, 1270-2.

FEES.

Verification Fees:—

At Kew Observatory the testing of instruments is made self-supporting, (*Galton, F.*) 424.

The testing of instruments for commercial use at the national physical laboratory, if established, might be made largely self-supporting, (*Thompson*) 1052-3; (*Swinburne*) 1389, 1439; (*Samuelson*) 1515; (*Ayrton*) 2011.

The standardizing of high-class scientific instruments should be paid for by the State, (*Kelvin*) 1149.

Scale of Fees charged at the Board of Trade Electrical Laboratory, Appendix A.

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Fees Charged for Investigation:

The cost of experiments carried out at a national physical laboratory, if established, for the Woolwich Arsenal or for the Post Office should be paid by the Department for which they were undertaken, (*Anderson*) 1674-5; (*Preece*) 2038-9.

Manufacturers would be willing to pay for similar assistance, the results of the investigations being published, (*Crompton*) 1344-8; (*Gray*) 1485; (*Anderson*) 1671-3, 1696-9; (*Preece*) 2045-7; (*Hadfield*) 2351-3.

No considerable income could be made by charging fees for investigations or the determination of constants, (*Samuelson*) 1515; (*Swinburne*), 1436-40; (*Bell*) 2298-2301.

FOSTER, PROFESSOR G. CAREY.

Nominated by the British Association.

For evidence see pp. 36-9. Analysis:—

The work of a national physical laboratory should be confined to the purely routine work of testing measuring instruments and making careful examinations of standard values; such work could be carried on with great economy of labour by a body specially devoted to it, 933-6, 949-52, 971-90. The governing body should select the subjects to be investigated, 960. Investigations should be continually made with a view to obtaining greater accuracy of the electrical standards, 941-7, 997-1001. A re-determination of the absolute value of the ampere particularly needed, 946. The Kew Standard thermometer is not a satisfactory standard, and should be compared with a gas thermometer, 963-6. The Kew Magnetic Observatory should be improved, 941. The verification of instruments should be undertaken by an impartial authority supported by

FOSTER, PROFESSOR G. CAREY—*continued.*

the State, 977-990. The industrial bodies should be represented on the governing council of a national laboratory, if established, as well as scientific bodies, 953-5. The executive head should be a man of considerable scientific attainments, 953. The site of Kew Observatory is a suitable one for a physical laboratory, 956.

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Investigation needed as to the failure of, (*Preece*) 2034, 2065-74.

FUSING POINTS OF METALS AND ALLOYS.

Determination of, needed, (*Preece*) 2034; (*Hadfield*) 2312-21.

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GALTON, SIR DOUGLAS.

For evidence see pp. 1-5. Analysis:—

Sketches the history of the movement in favour of establishing a national physical laboratory, 1-3. Describes the organisation and work of the Physikalisch-technische Reichsanstalt, 4-17, 39-44. Believes that it is not proposed to unite the Weights and Measures Department at Charlottenburg with the Reichsanstalt, 35-6, 39. The provision of accurate standards and the carrying out of investigation are of great industrial importance; research is continually required in connection with standards, 18-19, 24-26. The work of Kew Observatory should be extended in the direction of the second division of the Reichsanstalt with some auxiliary research in the establishment itself; the site of Kew is suitable for physical work, 19, 22, 45. The electrical part of the work of the Board of Trade should be developed, 27-33. The management of a national laboratory, if established, should be entrusted to a Board of Visitors nominated partly by the Government and partly by the Royal Society; the director should be a man of high scientific position, 19.

GALTON, MR. FRANCIS.

Chairman of the Kew Observatory Committee.

For evidence see pp. 15-19. Analysis:—

Sketches the history of the Kew Observatory, 323; organisation and government, 330-9; relations to Government, 325-9; to the Meteorological Council, 373-6. Site of the Observatory suitable, 377-81. Desirable that a standardizing institution should sometimes go ahead of the trade demand for tests, 365. The testing of instruments at the Kew Observatory has led to a considerable improvement of the instruments, 353, 361, 367, 397. Fees are charged for testing so as to make the work self-supporting, 424. Desirable that the testing of instruments at Kew should be extended, 382-5. The introduction of a new test frequently requires much costly previous work, 323. Importance of the magnetic work at Kew, 409-14. The work at Kew greatly hampered by the smallness of the scientific staff, 330-9. If the work were largely extended the management should be entrusted to a large committee, meeting annually, who should appoint a Council to be the *de facto* managers, 342-4, 428. Desirable that the members of the Council should not be paid for their services, 426-7.

GALVANIC ACTION.

Importance of investigation of, in relation to propeller shafts, (*Kelvin*) 1118; (*Samson*) 2185.

GAS CYLINDERS.

Desirable that facilities be provided for the public testing of, the method of testing being laid down at a laboratory such as is contemplated, (*Kelvin*) 1097, 1153-4.

The existing means of testing, adequate, (*Maw*) 1711-4,

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GAUGES.

Engineers' gauges tested at the Standards Office, (*Chaney*) 229-36.

The gauges are used in different ways in different Government Departments, (*Anderson*) 1657.

Desirable that the method of using the gauges be fixed by a central authority, (*Anderson*) 1658.

Desirable that an impartial authority be established to decide in cases of disputed measurements, (*Anderson*) 1614-5; (*Maw*) 1765-6; (*Kennedy*) 2125*-7.

GLASS.

Investigation required of the properties of glass in connection with thermometry, (*Chree*) 548, 699; (*Lodge*) 915.

Testing of thermometers made of special glass at Kew Observatory, (*Chree*) 539-40.

Thermometers made with ordinary English glass show a depression of the zero of 1-10th or 2-10ths of a degree, (*Chree*) 623.

A French glass has been selected at the Bureau International, and a German glass at the Reichsanstalt, for standard thermometers, (*Chree*) 546-7.

Desirable that there should be an English institution where English glass could be independently tested, (*Chree*) 548.

Application to test glass for gauges made at Kew Observatory, test not undertaken at any institution in this country, 531-2.

GLAZEBROOK, MR. R. T.

Secretary of the Electrical Standards Committee of the British Association.

For evidence see pp. 29-32. Analysis:—

Describes the standardising and research work carried out at the Cavendish Laboratory in connection with the Electrical Standards Committee, 793-6, 824-8. The amount of testing work has been limited by charging a considerable fee, 796. Such work should not be carried out at a university, 800-1. Some of this work might be carried out at the Board of Trade Laboratory, 797-9. Does not regard the latter laboratory as a final arrangement, 830. Does not consider that the Board of Trade Laboratory is in a position to undertake work requiring very great accuracy, 802, 818, 854-61. Investigation is required as to the constancy of resistance coils, 796, 808. Important that the standard coil be periodically compared with a mercury standard, 809-17. Uncertainty exists as to the exact value of the electro-chemical equivalent of silver, 821-2, 847-9; also as to the best form of the Clark cell, 822-3. Means should be provided for testing new methods and devices for making measurements and comparisons before they are introduced into any national standardising department, 829-39.

GRAY, MR. R. K.

Nominated by the Institution of Electrical Engineers. For evidence see pp. 58-9. Analysis:—

Desirable that further facilities be provided for the standardising of electrical instruments, 1454-8. Would like to limit the work of a national laboratory to the question of standards, and to such research as might be necessary in connection with standards, 1461-4. The systematic determination of physical constants would be of great commercial value, but it would be difficult to limit the scope of such work, 1483-5. The selection of the investigations to be conducted must be made by the managing committee, 1464-8, 1486-7. The investigations made at the Reichsanstalt on manganin have been of great industrial importance, 1471-4. Experience as to the failure of resistance coils, App. D. A considerable sum is expended by manufacturing electricians in laboratory work, 1488-94. Considers that the government of the National Physical Laboratory, if established, should be entrusted to a committee nominated by the Royal Society, provided that technology be adequately represented on the Committee, and that the committee should not necessarily consist exclusively of Fellows of the Royal Society; considers that it might be desirable that representatives of the Colonies and of certain Government offices should be included on the committee, 1476-81.

GUILLAUME.

Alloy of nickel and iron discovered by, which does not expand under the influence of heat, (*Lodge*) 890, 896; (*Kelvin*) 1171.

HADFIELD, MR. R. A.

For evidence see pp. 92-4. Analysis:—

Many investigations of great technical importance cannot well be undertaken by private enterprize; they should be carried out systematically at a laboratory such as is contemplated, 2311-4, 2320-5. Uncertainty as to the melting points of metals and alloys, 2312, 2319-21. Pyrometry of great industrial importance, 2321-2. Preparation of pure metal greatly needed, 2323-4. Determination of the hardness of metals should be undertaken in a scientific manner, the term "hardness" is now used for several distinct properties, 2324-9. Manufacturers would be glad to consult such a laboratory and would pay for the assistance given, 2351-2. Desirable that facilities be provided for the official standardising of instruments, particularly of pyrometers, 2330, 2346. The investigation of the fatigue of metals should be undertaken in a national institution, 2329.

Considers that the technical world would be satisfied if the governing body of such a laboratory were composed partly of scientific men and partly of technical men, appointed possibly by the Royal Society, 2337-8. The selection of the subjects to be investigated might be made without serious difficulty by the governing body, 2334.

HARDNESS.

Existing knowledge of, very empirical. Subject cannot well be investigated by manufacturers; should be undertaken at a national institution, (*Hadfield*) 2324-9.

HEAT, CONDUCTION AND RADIATION OF.

Investigation needed as to the radiation of heat from the parts of engines and from steam pipes and flanges, particularly as affected by the form of the object from which the radiation is taking place, (*Maw*) 1875; (*Samson*) 2185. Subject proposed for investigation by a Research Committee of the Institution of Mechanical Engineers; might be undertaken at a laboratory such as is contemplated (*Maw*) 1875-6.

Questions as to the conduction of heat through boiler plates are of great technical importance; might be investigated in a national physical laboratory, (*Ayrton*) 2003.

HOPKINSON, DR. JOHN.

Nominated by the Institution of Civil Engineers.

For evidence see pp. 61-4. Analysis:—

Many classes of scientific investigation, such as investigations into the constancy of physical properties, and the systematic determination of physical constants should be carried out by paid officials; there is no adequate motive for individuals to carry them on to the extent that is desirable, 1531-4. The systematical determination of physical constants conducted by a public body would be of great industrial importance, 1568-79, 1586-90. Results of private tests are frequently not published at all or published in a somewhat inaccessible form, 1573-83. Desirable that an institution be established whose duty it would be to provide for the standardizing of new classes of instruments when necessary, 1534. The testing of instruments may be conveniently done by the State, 1564-5. The scientific accuracy of standards should not be limited to that required for commercial purposes, 1537. The establishment of a national physical laboratory would strengthen the position of those who have to manage the Board of Trade Electrical Laboratory, 1538-9, 1546. The Board of Trade Laboratory should not be superseded, 1539, 1566-7. Desirable that the management of such a laboratory be entrusted to the Royal Society, and that technology be represented on the governing committee, 1541-4. The governing body should not undertake to give private reports on investigations, 1584-5, 1605-6. The site of Kew Observatory would be a suitable one for a national physical laboratory, 1547-9.

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HYDROMETERS.

Instruments for manufacturers are not tested at the Standards Department; believes that they can get standard Sykes' hydrometers for Revenue purposes indirectly standardized at Somerset House, (*Chaney*) 217-225.

Tested at Kew Observatory, (*Chree*) 475-8, 677-85.

HYGROMETERS.

For meteorological purposes wet and dry bulb hygrometers almost exclusively used; the thermometers for these instruments are tested at Kew Observatory, (*Chree*) 625-36.

INSULATION RESISTANCE.

of materials, importance of determination of the effect of heat on, (*Crompton*) 1289, 1295-6; (*Obach*) 1929.

Desirable that means be provided for the official testing of the quality of certain insulating substances, (*Gray*) Appendix D.

See also *Cables*.

KELVIN, LORD.

Nominated by the Royal Society.

For evidence see pp. 42-7. Analysis :—

A scientific institution is necessary to supplement the work of the Board of Trade Laboratories by providing standards with instructions as to the method of using them, 1092-4, 1124. Such an institution should perhaps exert an official advisory superintendence over the Standardizing laboratories, and the latter should have a right to demand help from the institution, 1123-5, 1140. Scientific instruments should be tested without fees at such a laboratory, 1148-50. The testing of commercial instruments should be carried out at the Board of Trade laboratories, which should be made self-supporting, 1148. Verifying laboratories under the Board of Trade should be established in various places, 1121, 1153-4. Arrangements are specially needed for the testing of many electrical instruments, and of pressure gauges, 1091-2, 1095-7; gas cylinders, 1097. At a national laboratory should be undertaken many investigations of great scientific and commercial importance, *e.g.*, extension of thermometric scale and increased accuracy therein, 1098-1104; determination of the ratio of the electrostatic and electromagnetic units, 1107; method of measurement of the strength of a magnetic field, 1108-10; investigations on the fatigue of metals, 1114-7, 1157-64, 1187; on galvanic action in relation to propeller shafts, 1118; on the deterioration of brass, 1164. Much of this work cannot be carried out by private persons, 1105-6, 1117. Important that the site of such a laboratory be free from mechanical or electrical disturbances; the site of Kew Observatory would be suitable, 1111-2, 1174-8. If a laboratory were established in close proximity to the Kew Observatory it would be necessary to remove the magnetic instruments to a distance of about a quarter of a mile from it, 1178-9. The director of such a laboratory should be a man of the highest eminence, at a salary of at least £1,200 a year, 1119-20, 1141-5. The government of the laboratory might be entrusted to the Royal Society, who should appoint a committee, the members of which should not necessarily be Fellows of the Society, 1191-8. Desirable that such a laboratory be established on not too large a scale and be allowed to extend as the work increased, 1200-2. The scope of work of such a laboratory could be kept within moderate limits, 1136-40.

KENNEDY, PROFESSOR A. B. W.

Nominated by the Institution of Mechanical Engineers.

For evidence see pp. 84-7. Analysis :—

The standards of measurement required by engineers are now constructed with sufficient accuracy for practical purposes, 2091-2. Desirable that means should be provided for the official verification of steam engine indicator springs, 2085, 2121. It would be convenient if an institution were established to test standard instruments, and pyrometers, and to authoritatively pronounce upon a disputed measurement, 2085-7, 2121-7. In many cases the calibration of instruments must be done in place, 2087-8, 2090, 2143. Considers that the systematic determination of physical constants would be useful for industry, but that investigations which are obviously technical would not be better carried out by a central official institution than, for instance, by the Research Committees appointed by the Institution of Mechanical Engineers, 2093-2102, 2133-4, 2165-6. Investigations of great technical importance, such as the determination of the most suitable materials for certain mechanical purposes, might be carried out in a laboratory such as is contemplated, 2114*, 2118-20, 2128-30, 2144-63. The testing of copper tubes and boiler tubes, and investigations on such matters, would be of little service unless conducted by men technically conversant with the subjects, 2111-5. The existing arrangements for testing copper pipes are satisfactory, 2111.

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Considerable vagueness as to, (*Lodge*) 918; (*Swinburne*) 1407-8; (*Ayrton*) 1989-90.

A 50-candle standard is needed, (*Ayrton*) 1989.

No standard of gas burner except in the case of the Metropolitan Gas Light Acts, (*Chaney*) 114.

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Should be established by a central authority, (*Swinburne*) 1407-8; (*Ayrton*) 1989.

LODGE, PROFESSOR O. J.

Nominated by the Royal Society.

For evidence see pp. 32-6. Analysis :—

Describes the class of physical work which should be carried out in a national laboratory, 865-914. Such work cannot be conveniently performed by universities or by private persons, 865, 880-4. Great care should be taken by the governing body of such a laboratory, if established, to avoid interference with the research work of individuals, 869, 928. The establishment of an institution for accurate standards would be of great benefit to industry, 866-7, 900. The investigations carried out at such a laboratory, if established, would probably have a very valuable effect on trade and commerce, 890-914. The laboratory should be governed by a director of considerable eminence subject to a council of advice, 879. The Kew Observatory might advantageously be developed into a national physical laboratory, 925-8.

MAGNETIC INSTRUMENTS.
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Half the actual observatories of the world have had their magnetic self-recording instruments verified at the Kew Observatory, (*Chree*) 442-7.
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MANGANIN.
Discovered and largely studied at the Reichsanstalt; is of great commercial importance for resistance coils, (*Crompton*) 1284 ; (*Gray*) 1471-5 and App. D ; (*Obach*) 1946-7 ; (*Ayrton*) 2015.
Unsuitable for high-class standard resistance coils, (*Obach*) 1946.

MARINE DEPARTMENT, BOARD OF TRADE.
Further provision needed for the testing and verification of instruments used by, (*Samson*) 2172-4, 2196-9.
Many constants and numerical data and formulæ used by the Department should be re-determined and new data obtained relative to certain subjects (list given), 2176-8, 2185.
The details of experiments conducted by the Department are not completely published ; the experiments cannot be made in such a manner as to connect the various series together: it would be of great service if a Government authorised body could conduct experiments and carry out investigations for the Department, 2179-80, 2186-95.

MATERIALS, TESTING OF.
See *Brass.—Copper.—Insulation Resistance.*

MAW, MR. W. H.
Nominated by the Institution of Mechanical Engineers. For evidence see pp. 67-73. Analysis :—
The existing institutions meet the practical requirements of engineers as regards the construction of standards and the testing of instruments, 1706-17. The difficulties that exist at present in respect to measurements arise from faulty use of the gauges or from not getting the gauges verified, 1749-57. It would be convenient if an impartial institution were established to give an authoritative decision in case of disputes as to measurements, 1765-6, 1862. Desirable that the Government should establish a standard system of screws, 1767-81. The testing of pressure gauges by the makers is sufficient for practical purposes, 1708-10, 1784-87. The existing means for testing gas cylinders are adequate, 1711-14, 1820-22. The present arrangements for testing copper steam pipes are satisfactory, 1834-49. Describes the work of the Research Committees appointed by the Institution of Mechanical Engineers, 1722-5, 1811-9. The number of researches undertaken has been limited by the funds available, 1879. (For list of subjects suggested for research to the Council of the Institution see Appendix E). Some of the subjects already investigated and also of those suggested for investigation might be studied in a physical laboratory, 1723, 1858-60, 1876. Many scientific investigations which bear upon mechanical engineering might be carried out in a physical laboratory, but not purely mechanical engineering researches, 1723, 1726-7. Doubts whether the investigation of the effect of vibrations on the strength of materials could be better carried out in a laboratory such as is contemplated than by the people directly interested in the facts, 1728-31. Describes the present practice of railway companies in respect to the failure of crank axles, 1796-1807, 1885-9. Does not consider that scientific experiments on this subject would be of much practical use, 1824*-33. The investigations conducted by a railway company on such subjects do not extend beyond their own requirements, 1809-10. Does not know of any particular physical constants that at present require verification for the mechanical engineer, 1721.

METEOROLOGICAL OFFICE.
Relations of, to Royal Society and to Government, (*Scott*) 1214-21.
Relation to Kew Observatory, 373-6, 439-41, 1207-10.
Work of, (*Scott*) 1222-4, 1240-53.

MICROMETERS.
Need of impartial test of, (*Swinburne*) 1397, 1405; (*Samson*) 2172-4.
See also *Gauges.*

MUTUAL INDUCTION.
Need of Standard of, (*Ayrton*) 1992.

NATIONAL PHYSICAL LABORATORY, A.

Government of:
That the government be entrusted to the Royal Society, who should appoint a committee of management, the members of which should not necessarily be members of the Royal Society, and on which technology should be largely represented, considers (*Kelvin*) 1166-8, 1192-8; (*Crompton*) 1301-2, 1307; (*Swinburne*) 1417, 1428-30, 1443-53 ; (*Gray*) 1476-81; (*Hopkinson*) 1541-5; (*Anderson*) 1628-32 ; (*Obach*) 1918-20; (*Strachey*) 1962, 1965-6 ; (*Preece*) 2053-5 ; (*Hadfield*) 2337-8.
Some of the members of the committee of management should be appointed by certain technical societies, (*Foster*) 953-5; (*Samuelson*) 1508-12, 1519-22 ; (*Ayrton*) 2009.
The management should be entrusted to a board of visitors, nominated partly by the Government and partly by the Royal Society, (*Galton, D.*), 19.
The managing body should consist of a large committee, meeting annually, who should appoint a council to be the *de facto* managers, (*Galton, F.*) 342-3, 425-53.

Director:
Should be a man of high scientific eminence, (*Galton, D.*) 19 ; (*Foster*) 953 ; (*Thompson*) 1024 ; (*Kelvin*) 1119-20, 1141-5 ; (*Crompton*) 1303 ; (*Anderson*) 1677-8.
Should be an able scientist, but should also have had some training in the practical world, (*Preece*) 2053, 2078.
Desirable that he should devote his whole time to the work, in which case the salary offered should not be less than £1200, (*Kelvin*) 1119-20 ; £1500, (*Preece*) 2059 ; should be about £2000, (*Anderson*) 1678-80.

Site:
The site of such a laboratory must be free from mechanical or electrical disturbances, and should be not far from London ; the site of Kew Observatory would be suitable, (*Galton, D.*) 22 ; (*Bidwell*) 726-9 ; (*Lodge*) 925 ; (*Foster*) 956 ; (*Kelvin*) 1174-8 ; (*Samuelson*) 1525 ; (*Hopkinson*) 1547-9 ; (*Strachey*) 1960-1, 1963-5 ; (*Ayrton*) 2007-8 ; (*Preece*) 2049-52.
If it were decided to establish such a laboratory by an extension of Kew Observatory it would be necessary to erect a building at some distance from the existing building or to move the magnetic self-recording instruments from their present position, (*Foster*) 957-8 ; (*Kelvin*) 1178-9.

Publication of Results:
All investigations carried out in such a laboratory, if established, should be freely published, (*Samuelson*) 1513 ; (*Hopkinson*) 1584-5, 1605-6; (*Swinburne*) 1431-5 ; (*Ayrton*) 2006 ; (*Preece*) 2046.
It might be desirable to give a private report on an incomplete investigation, (*Crompton*) 1371-7.
Desirable to be able to give a private report and withhold publication for a certain time, (*Anderson*) 1682-98.

Private Research:
It might be desirable to allow a person to make use of a portion of the building and of apparatus to conduct a private investigation on payment of a fee, (*Crompton*) 1366-8.
Provision should be made for, (*Preece*) 2031-2.

Relation to Board of Trade Standardizing Laboratories:
That the construction of many standards should be carried out in such a laboratory and that the testing of commercial instruments by means of these standards be carried out in the Board of Trade Laboratories, approves, (*Thompson*) 1050-2 ; (*Kelvin*) 1121-5 ; (*Crompton*) 1313-7, 1351-9.

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NATIONAL PHYSICAL LABORATORY, A—*continued.*

That the governing body of such a laboratory should advise the Board of Trade, when required, and should have a general visiting power over the Board of Trade Laboratories, (*Kelvin*) 1125; (*Crompton*) 1357-63; (*Ayrton*) 2010.

See also *Fees; Standardizing of Instruments; Physical Constants and Numerical Data.*

OBACH, DR. EUGENE F. A.

For evidence see pp. 73-6. Analysis :—

Describes the difficulties arising in technical work from the absence of data respecting physical constants, 1897-8. The determination of constants should be carried out systematically in a national institution, 1897, 1908-11. No serious difficulty would arise in selecting the subjects to be investigated, 1901-2. Considers it of great importance that a subsidiary chemical laboratory be attached to such an institution to test the purity of the materials used and to study the methods of producing pure materials, 1903-7, 1949-53. The work of such a laboratory would not interfere with that of the private investigator, 1909-10. Arrangements should be made to work in harmony with similar institutions in other countries, 1912-3. The standardizing of instruments would be of great value to the trade, 1930-7. For such work an extension of Kew is desirable, 1918. Considers that the government of a national laboratory, if established, should be entrusted to the Royal Society, provided that technology be adequately represented on the governing body, which should not necessarily consist exclusively of Fellows of the Society, 1918-20. The institution should be associated with the existing Government standardizing offices, 1922-3.

OHM.

Re-determination of, desirable, *(Glazebrook)* 796, 808; *(Ayrton)* 1995.

Question as to the constancy of the temperature coefficients of certain resistance coils, *(Glazebrook)* 796-7, 802.

Standard ohm should be periodically compared with a mercury standard, *(Glazebrook)* 809-17.

OPTICAL INSTRUMENTS.

Great need of further facilities for testing, (*Thompson*) 1011; (*Ayrton*) 1986-8.

Extension of testing of, at Kew Observatory desirable, (*Chree*) 484, 550.

Application for testing of, received at Kew Observatory, (*Chree*) 530, 536.

PENSIONS.

In forming an establishment with officers and clerks necessary that some arrangement be made for giving the staff pensions or superannuation in some form; the Civil Service rules satisfactory, (*Strachey*) 1967-77.

PHOTOGRAPHIC LENSES.

Method of testing of, at Kew Observatory, should be somewhat altered, (*Galton, F.*) 403-4; (*Chree*) 483-4, 550.

PHOTOMETRY.

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PHYSICAL CONSTANTS AND NUMERICAL DATA.

The determination of, necessary in connection with the construction and use of standards, (*Galton, D.*) 19; (*Chaney*) 143-56; (*Foster*) 946-50, 1001; (*Glazebrook*) 793, 808-23, 829-39; (*Lodge*) 865-8; (*Gray*) 1461-3; (*Ayrton*) 1995. The determination of, should be carried out in a systematic and continuous manner, (*Bidwell*) 712-7, 757-60; (*Lodge*) 865, 890; (*Foster*) 935; (*Samuelson*) 1502; (*Hopkinson*) 1552, 1579; (*Obach*) 1898, 1911; (*Samson*) 2179

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The determination of, cannot be satisfactorily carried out by private enterprise, (*Bidwell*) 714, 768; (*Lodge*) 880-3; (*Foster*) 936; (*Thompson*) 1014, 1022-3; (*Kelvin*) 1105-6; (*Samuelson*) 1502-6; (*Hopkinson*) 1531-4, 1587; (*Hadfield*) 2312.

The systematic determination of, undertaken for scientific purposes would probably lead to results of great technical value, (*Bidwell*) 734-5, 761; (*Lodge*) 890, 895-7, 902-4; (*Kelvin*) 1172.

Determination of many physical constants and numerical data required for industrial purposes could be undertaken in a physical laboratory, (*Lodge*) 865, 890-6; (*Foster*) 969-70; (*Thompson*) 1019-20; (*Kelvin*) 1098-1104, 1114-8; (*Samuelson*) 1502-5; (*Hopkinson*) 1534; (*Anderson*) 1639-41, 1647; (*Maw*) 1723, 1852; (*Obach*) 1897-1900; (*Ayrton*) 2003-4; (*Preece*) 2031-4; (*Kennedy*) 2165-6; (*Samson*) 2177-85; (*Bell*) 2277-8; (*Hadfield*) 2312-6, 2320-5.

Difficult to limit the scope of such work, considers, (*Crompton*) 1300-1; (*Gray*) 1483; (*Bell*) 2260-2, 2291.

The selection of the subjects to be investigated in a national laboratory, if established, might be made without much difficulty by the governing body of the laboratory, (*Foster*) 960; (*Thompson*) 1015-7, 1048-9; (*Kelvin*) 1137-40; (*Swinburne*) 1413-4; (*Obach*) 1901-2; (*Ayrton*) 2009; (*Preece*) 2060.

Part of the cost of such work might be covered by fees, (*Crompton*) 1344-8; (*Gray*) 1485; (*Anderson*) 1671-3; (*Preece*) 2045-7.

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Staff of; standards and instruments used by; testing work of, (*Preece*) 2020-5.*

Further facilities required for the testing of instruments, (*Preece*) 2026-9.

Hampered by the want of knowledge of certain physical constants and numerical data; the time of the staff is largely engrossed by the determining of such data and the carrying out of investigations; desirable that such work be carried out at an independent institution; the cost of investigations made at such an institution for the Post Office might be paid for by the Department, (*Preece*) 2030-1, 2034-43.

PREECE, MR. W. H.

Engineer-in-Chief and Electrician to the Post Office.

For evidence see pp. 81-4. Analysis :—

Describes the testing arrangements at the General Post Office, 2020-5.* The Board of Trade Electrical Laboratory should be supplemented by some other institution, 2026-8. A national physical laboratory should be established to test instruments for physical investigation and to construct and preserve standards, and to carry out investigations for Government departments, the cost of which should be paid by the Department concerned, 2028-30, 2038-43. Is greatly hampered by the want of physical data, particularly in relation to specific resistances of saline solutions, the fusing points of alloys, specific inductive capacity, and magnetic permeability, 2030-1, 2034. Physical constants and numerical data should be determined at a national laboratory, 2031. Investigation needed as to the cause of failure of fuses, 2065-75. The governing body would be able to restrict the number of investigations to be carried on, 2060. The work of such a laboratory would not interfere with that of the private investigator, 2061. Some provision should be made for private research, 2031-3. Considers that such a laboratory would be largely self-supporting, 2044-7. The results of all investigations carried out at a public laboratory should be published, 2046.

The government of a national laboratory, if established, should be entrusted to the Royal Society, the committee of management should contain representatives of industry and of commerce and technology, 2053-5. The director should be a man of consider-

PREECE, MR. W. H.—*continued.*
able scientific eminence, who has also had some training in the practical world; the salary offered should not be less than £1,500 a year, 2056-9, 2078.
The site of Kew Observatory is very suitable for physical laboratory, 2049.
Considers that an electric railway could not produce any serious magnetic disturbance at a point distant a mile and a half, provided there were a complete metallic return, 2050-2.

PRESSURE GAUGES.
Standard, should be established, (*Samson*) 2183, 2198-9.
Desirable that facilities be provided for the public testing of, (*Kelvin*) 1095-6; (*Anderson*) 1616-20; (*Ayrton*) 1982-3.
Considerable trade demand for the testing of, (*Chaney*) 165-6.
Considers the present facilities for the testing of, sufficient for practical purposes, (*Maw*) 1708, 1784-7.
Desirable that facilities be provided for the official testing of standard pressure gauges, (*Kennedy*) 2121-2; (*Samson*) 2198.

PYROMETERS.
Increased accuracy in, of great commercial importance, (*Kelvin*) 1101-4; (*Hadfield*) 2321-2.
Simplification of, needed for commercial purposes, (*Samuelson*) 1501; (*Hadfield*) 2322.
Desirable that further facilities be provided for the testing of, (*Anderson*) 1615-6; (*Maw*) 1792; (*Obach*) 1930-5; (*Kennedy*) 2123-5; (*Samson*) 2172-4.

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See *Heat, conduction and radiation of.*

RAILS, STEEL.
Important to ascertain the cause of failure of; investigation might be carried out at a laboratory such as is contemplated, (*Kelvin*) 1187; (*Hopkinson*) 1580-2, 1592-7; (*Maw*) 1739; (*Bell*) 2277-8, 2285-9, 2295-7.
The investigation as to the failure of, would be carried out within their own requirements by the industrial bodies concerned, (*Maw*) 1731.

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REICHSANSTALT, PHYSIKALISCH-TECHNISCHE.
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SAMSON, MR. PETER,
(Engineer Surveyor-in-Chief to the Board of Trade.)
For evidence see pp. 87-8. Analysis:—
Further facilities should be provided for the official testing of instruments, 2172-4, 2183, 2196-9. A standard pressure gauge should be constructed, 2183, 2198-9. Desirable that an institution be established to carry on research and other kindred work, collect and publish useful data, revise or determine physical constants, and keep and fix standards; it would be economical that such work should be done in a systematic way, 2177-81. Gives examples of subjects in reference to which investigations are required, 2185. It would be of great service to the Marine Department of the Board of Trade, and to the public, if such experiments could be carried out by an official body, 2179-80, 2186-95. It would be a great advantage if the Government would define a system of threads for all sizes of screws, and arrange with the colonies and foreign countries to adopt the same system; it would be desirable to adopt the metric system of screws, 2200-3.

SAMUELSON, SIR BERNHARD.
(Nominated by the Iron and Steel Institute.)
For evidence see pp. 60-1. Analysis:—
The simplification of pyrometers would be of great industrial value, 1501. Many physical investigations of great importance cannot well be undertaken in private laboratories, *e.g.*, investigations as to the effects of stress upon metals; investigations as to the best kind of steel for boiler tubes; experiments on fatigue, 1502-7. The testing of instruments might be made self-supporting, 1515. The results of all investigations carried out in a national laboratory should be published, except those undertaken for the Government, 1513-5. Government departments should have a right to apply to such a laboratory for assistance; the committee of management of the laboratory should exercise a directing influence over the other Government standardising institutions, 1516-8. The governing body should be nominated partly by the Royal Society and partly by certain technical institutions, the nominees of the technical institutions being added subject to the consent of the Royal Society, 1508-12, 1519-23. The Old Deer Park, Richmond, is a suitable site for a physical laboratory, 1525.

SCOTT, MR. R. H.
(Nominated by the Royal Meteorological Society.)
For evidence see pp. 47-9. Analysis:—
The facilities at Kew Observatory are sufficient for the testing of meteorological instruments, except anemometers, 1207-10. On account of the small temperature range in England it is not necessary that meteorological thermometers should be corrected to the gas thermometer, 1232-3. Electrical instruments cannot be tested at Kew on account of the proximity of the magnetic observatory, 1211. Describes the relation of the Meteorological Council to the Royal Society, 1214-21; the practical uses of the weather work of the Meteorological Office, 1224. Considers the determination of wind pressure of great practical importance; describes the experiments on the subject made by the Meteorological Office, 1240-57. The mark placed upon instruments verified at Kew Observatory is not registered, 1224-31, 1257-9.

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STRACHEY, SIR RICHARD,
Chairman of the Meteorological Council.
For evidence see pp.76-7. Analysis :—
Further facilities should be provided for the testing of instruments, 1957-8. Highly important that there should be an establishment for the systematic determination of physical constants and numerical data, 1959. Such an establishment could best be produced by a development of the Kew Observatory, 1960-1, 1963-4. The general control of such an institution, if established, should be entrusted to the Royal Society, 1962. Desirable that commercial interests should be represented on the governing body, which should not necessarily be composed exclusively of members of the Royal Society, 1965-6.
Considers it of great importance that in any such establishment a system of pensions, or some equivalent, be provided for the staff, 1967-77.

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SWINBURNE, MR. J.
Nominated at the Institution of Electrical Engineers.
For evidence see pp. 54-8. Analysis :—
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i. GENERALLY.

The extension of the thermometric scale both up and down and increased accuracy in it is of immediate

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on 31 October, 2019

THERMOMETRY—*continued.*

practical importance and will be of greater practical importance in the future. No private individual can undertake the necessary investigations on the subject, (*Kelvin*) 1098-1106.

The very accurate measurement of temperature of great importance in connection with electrical testing, (*Crompton*) 1286-7; (*Obach*) 1931-3, 1940.

Commercial importance of accurate pyrometry, (*Kelvin*) 1101-4; (*Samuelson*) 1561; (*Bell*) 2302-4; (*Hadfield*) 2321-2.

ii. STANDARD THERMOMETERS.

No (legal) standard of the Fahrenheit thermometer in England; legal position in respect to thermometry not wholly satisfactory, (*Chaney*), 116-128.

Gas Thermometers:

Adopted as the ultimate standard at the Bureau International and at the Reichsanstalt, (*Chree*) 465.

Uncertainty as to the accuracy of, at high temperatures, (*Kelvin*) 1101.

Not been established at Kew on account of want of funds and smallness of staff, (*Chree*) 471-4, 644-6, 693-8.

Mercury-in-Glass Thermometers:

Cannot be used to measure temperatures above 500 deg. Cen., (*Chree*) 509.

Kew standard not satisfactory; scale of, should be compared directly with the scale of the gas thermometer, (*Chree*) 581, 686-94, 699; (*Kelvin*) 1098.

French standards from the Bureau International used at the Standards Office, (*Chaney*) 116.

French standards verified at the Bureau International used at Kew for verification of certain thermometers for scientific purposes; no certificates given with thermometers so verified, (*Chree*) 464-6, 617.

Verre dur glass used for standard thermometers at Bureau International, Jena glass used at Reichsanstalt, (*Chree*) 546-7.

Ordinary English glass thermometers show a relatively high depression of the zero, (*Chree*) 623-4.

Platinum Thermometers:

Arrangements for comparison of scale of, with that of hydrogen thermometer at Bureau International, made by the Kew Committee, (*Chree*) 507-9.

Constancy of zero of, tested at Kew Observatory, (*Chree*) 509.

Much investigation required in connection with, (*Lodge*) 915.

Wide divergence of temperature co-efficient of different samples of professedly pure platinum, (*Crompton*) 1284.

Thermo-electric Junctions.

Importance of, for measurement of low temperatures, (*Kelvin*) 1098.

Investigation needed as to the most suitable materials for, (*Obach*) 1941-3.

See also *Pyrometers.*

iii. VERIFICATION OF THERMOMETERS.

Standards Office.—Cannot undertake verification of thermometers, except those for use with gas measuring apparatus and petroleum apparatus. Method of verifying thermometers, (*Chaney*) 114-139.

Kew Observatory.—Standard thermometers, (*Chree*) 569; meteorological thermometers, (*Chree*) 452-8, 583-7, 619-20; clinical thermometers, (*Chree*) 449-51, 456, 558-61.

Improvement of clinical thermometers sent for testing, (*Galton, F.*) 396-7.

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Nominated by the Physical Society.

For evidence see pp. 39-42. Analysis:—

Desirable that an institution be established for the testing of instruments, particularly for the testing of optical instruments, 1006-13, 1055-61, 1074-6. Advantageous that such work be done by the State, 1036-41. At such an institution should be undertaken the compilation of statistical information on scientific matters, 1014-23, 1076-83. The extent of the work could easily be limited by the director or governing body, 1015-7, 1043-9. Even on a small scale it might be of considerable service to industry, 1017-20. This work should not be carried out at Universities or Colleges, 1022-3.

The testing of commercial instruments would to a large extent be self-supporting, 1050-2. The director of a national laboratory, if established, should be a man of high scientific attainments and should be controlled by a committee not exclusively composed of scientific men, 1024-6, 1062-3, 1070-2.

VISCOMETERS,

Application to test, received at Kew Observatory, (*Chree*) 533-5.

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WRIGHT-COLE, MR. RICHARD.

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